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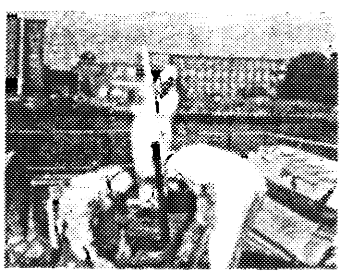

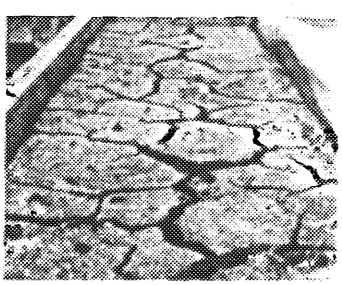

TECHNICAL REPORT EL-88-15

NEW BEDFORD HARBOR SUPERFUND PROJECT ACUSHNET RIVER ESTUARY ENGINEERING FEASIBILITY STUDY OF DREDGING AND DREDGED MATERIAL DISPOSAL ALTERNATIVES

Report 11

EVALUATION OF CONCEPTUAL DREDGING AND DISPOSAL ALTERNATIVES

by

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Report 11 of a Series

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Environmental Laboratory

NEW BEDFORD HARBOR SUPERFUND PROJECT, ACUSHNET RIVER ESTUARY ENGINEERING FEASIBILITY STUDY OF DREDGING AND DREDGED MATERIAL DISPOSAL ALTERNATIVES

No. in Series	Report Title
1	Study Overview
2	Sediment and Contaminant Hydraulic Transport Investigations
3	Characterization and Elutriate Testing of Acushnet River Estuary Sediment
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5	Evaluation of Leachate Quality
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8	Compatibility of Liner Systems with New Bedford Harbor Dredged Material Contaminants
9	Laboratory-Scale Application of Solidification/Stabilization Technology
10	Evaluation of Dredging and Dredging Control Technologies
11	*Evaluation of Conceptual Dredging and Disposal Alternatives*
12	Executive Summary

Unclassified

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This report evaluates conceptual dredging and disposal alternatives for the Acushnet River Estuary, a part of the New Bedford Harbor Superfund Site. Dredging for removal of the highly contaminated sediment and subsequent disposal in upland or nearshore confined disposal facilities or disposal in contained aquatic disposal facilities are alternatives considered in the "Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives." Sediment testing and sediment transport modeling performed as earlier tasks of the study form the basis for evaluation of the alternatives.

The technical feasibility of conceptual design options is based on site availability, capacity, and characteristics and on sediment physical characteristics and dredged material settling behavior as defined by laboratory testing. Contaminant releases during dredging and disposal operations are estimated for each disposal option. A preliminary cost estimate for implementation of each option evaluated is also presented.

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Confined disposal facility
Contained aquatic disposal
Contaminated sediment
Dredged material
Dredging
Feasibility study
Metals
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Remedial alternatives
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PREFACE

This study was conducted as a part of the Acushnet River Estuary Engineering Feasibility Study (EFS) of Dredging and Dredged Material Disposal Alternatives. The US Army Corps of Engineers (USACE) performed the EFS for the US Environmental Protection Agency (USEPA), Region 1, as a component of the comprehensive USEPA Feasibility Study for the New Bedford Harbor Superfund Site, New Bedford, MA. This report, Report 11 of a series, was prepared by the US Army Engineer Waterways Experiment Station (WES) and the New England Division (NED), USACE. Coordination and management support was provided by the Omaha District, USACE, and dredging program coordination was provided by the Dredging Division, USACE. The study was conducted between August 1985 and July 1988.

Project manager for the USEPA was Mr. Frank Ciavattieri. The NED project managers were Messrs. Mark J. Otis and Alan Randall. Omaha District project managers were Messrs. Kevin Mayberry and William Bonneau. Project managers for the WES were Messrs. Norman R. Francingues, Jr., and Daniel E. Averett.

This report was prepared by Mr. Daniel E. Averett, Water Supply and Waste Treatment Group (WSWTG), Environmental Engineering Division (EED), Environmental Laboratory (EL), WES; Dr. Michael R. Palermo, Research Projects Group, EED; Mr. Mark J. Otis, New Bedford Superfund Project Office, Operations Division, NED; and Ms. Pamela B. Rubinoff, Coastal Engineering and Survey Section, Engineering Division, NED. Technical support in preparation of the report was provided by Mr. Bret Perry, WSWTG. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

This study was conducted under the general supervision of Mr. Norman R. Francingues, Jr., Chief, WSWTG; Dr. Raymond L. Montgomery, Chief, EED; Dr. John Harrison, Chief, EL; Mr. Vyto Andreliunas, NED; and Mr. David Mathis, Dredging Division, USACE.

COL Dwayne G. Lee, EN, was the Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
gallons (US liquid)	3.785412	cubic decimetres
horsepower (550 foot-pounds (force) per second)	745.6999	watts
inches	2.54	centimetres
miles (US nautical)	1.852	kilometres
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square metres
yards	0.9144	metres

NEW BEDFORD HARBOR SUPERFUND PROJECT, ACUSHNET RIVER ESTUARY
ENGINEERING FEASIBILITY OF DREDGING AND DREDGED MATERIAL DISPOSAL ALTERNATIVES

EVALUATION OF CONCEPTUAL DREDGING AND DISPOSAL ALTERNATIVES

PART I: INTRODUCTION

1. In August 1984, the US Environmental Protection Agency (USEPA) reported on the Feasibility Study of Remedial Action Alternatives for the Upper Acushnet River Estuary above the Coggeshall Street Bridge, New Bedford, MA (NUS Corporation 1984a). The USEPA received extensive comments on the proposed remedial action alternatives from other Federal, state, and local officials, potentially responsible parties, and individuals. Responding to these comments, the USEPA chose to conduct additional studies to better define available cleanup methods. Because dredging was associated with all of the removal alternatives, the USEPA requested that the US Army Corps of Engineers (USACE), the Nation's dredging expert, conduct an Engineering Feasibility Study (EFS) of dredging and disposal alternatives. A major emphasis of the EFS was placed on evaluating the conceptual design of dredging and disposal alternatives with respect to their implementability and potential for contaminant releases.

2. The technical phase of the EFS was completed in March 1988. However, as part of Task 8 of the EFS, the results of the study were compiled in a series of 12 reports, listed below.

- a. Report 1, "Study Overview."
- b. Report 2, "Sediment and Contaminant Hydraulic Transport Investigations."
- c. Report 3, "Characterization and Elutriate Testing of Acushnet River Estuary Sediment."
- d. Report 4, "Surface Runoff Quality Evaluation for Confined Disposal."
- e. Report 5, "Evaluation of Leachate Quality."
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h. Report 8, "Compatibility of Liner Systems with New Bedford Harbor Dredged Material Contaminants."

i. Report 9, "Laboratory-Scale Application of Solidification/ Stabilization Technology."

j. Report 10, "Evaluation of Dredging and Dredging Control Technologies."

k. Report 11, "Evaluation of Conceptual Dredging and Disposal Alternatives."

l. Report 12, "Executive Summary."

This report is Report 11 of the series. The results of this study were obtained from conducting EFS Task 7, elements 2 and 3 (see Report 1). However, Task 7 incorporates the results of Tasks 1 through 6 into the evaluation of dredging and disposal alternatives.

Background

3. A description of the New Bedford Harbor Superfund Site is provided in Report 1. The site includes the Upper Estuary of the Acushnet River, defined as the estuary and adjoining wetlands between the Wood Street Bridge and the Coggeshall Street Bridge (Figure 1), the New Bedford Harbor, and Buzzard's Bay as far as the southern limit of the polychlorinated biphenyl (PCB) closure zone (see Report 1). This EFS addresses only the Upper Estuary portion of the site.

4. General procedures for conducting feasibility studies for Superfund projects are provided in "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (USEPA 1988). Once the scope of the remedial investigation/feasibility study (RI/FS) process has been developed, the FS is conducted in three steps: development of alternatives, screening of alternatives, and detailed analysis of alternatives. The components of each of these processes are shown in Figure 2. The NUS Corporation FS proceeded through a similar process in 1984 and evaluated five cleanup options (NUS Corporation 1984a,b). The E. C. Jordan Company, under a contract with EBASCO Services, Inc., is expanding the NUS FS to include cleanup options for the entire New Bedford Harbor Superfund Site and to address all nonremoval, removal, detoxification/destruction, and disposal technologies. The USACE EFS provides information on implementability, effectiveness, and cost for dredging

and selected disposal alternatives that will be incorporated into the FS being prepared by E. C. Jordan Company.

NUS dredging and disposal alternatives

5. The NUS Corporation evaluated four remedial action alternatives for the Upper Estuary in its FS (NUS Corporation 1984a). Three of these alternatives included dredging to remove the contaminated sediments from the Upper Estuary. The fourth alternative consisted of construction of a channel along the western shoreline to bypass the freshwater flows of the Acushnet River and isolate these flows from the more contaminated sediments. The contaminated sediment in the remainder of the Upper Estuary was to be capped with clean sediments. Further evaluation of this nonremoval alternative is not included in this EFS. In September 1984, NUS published an addendum to its FS (NUS 1984b), which presented its evaluation of a fourth dredging alternative, contained aquatic disposal (CAD). The four NUS dredging and disposal alternatives are briefly described below. For a more detailed description of the alternatives developed by NUS, the reader is referred to the NUS reports.

6. Dredging with disposal in a partially lined, in-harbor containment site. This alternative consisted of constructing a temporary confined disposal facility (CDF) in the cove area on the western side of the Upper Estuary to contain material dredged from beneath the in-water embankment (dike) of a permanent CDF to be constructed on the eastern side of the Upper Estuary (Figure 3). Once the permanent CDF was constructed, contaminated sediment from the remainder of the Upper Estuary and from the temporary CDF would be dredged to a depth of 3 ft,* placed, and stored in the permanent CDF. Supernatant from the CDF would be treated, and the site would be capped with an impermeable geomembrane and covered with clean soil. The partial liner would cover only the interior dikes of the CDF.

7. Dredging with disposal in a lined, in-harbor containment site. This alternative follows the same construction sequence as for the first alternative (Figure 3), except that contaminated sediment from beneath all of the area for the permanent CDF would be removed and placed in the temporary CDF. The bottom and sides of the permanent CDF would be lined with an

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5.

impermeable geomembrane liner. The NUS Corporation suggested that placement of the liner would probably require dewatering of the CDF.

8. Dredging with disposal in an upland containment site. This alternative also requires the temporary CDF on the western side of the Upper Estuary in the cove. Dredged material would initially be dredged into the temporary CDF, where it would be held for initial consolidation and dewatering by decantation. Decanted water would be treated prior to release to the estuary. The dewatered dredged material would be excavated from the temporary CDF and trucked to an unidentified offsite upland CDF. The upland CDF would be fully lined for leachate collection and treatment.

9. Dredging with disposal in in-harbor subsurface cells. This alternative consists of disposal of contaminated sediment from the Upper Estuary in a number of subaqueous cells (Figure 4) in the bottom of the Upper Estuary (NUS Corporation 1984b). These cells are excavated by dredging to an elevation well below the depth of contamination. Contaminated dredged material is placed in the bottom of the cell and covered with a layer of clean sediment, which returns the Upper Estuary bottom to its original elevation. A CDF in the cove on the western shore would temporarily store the contaminated sediment from the first subarea or cell. A second temporary CDF would be constructed on the eastern side of the Upper Estuary for storage of clean sediment dredged from the first subarea at depths below the extent of contamination. The cells would be excavated, filled with contaminated sediment, and capped in a stepwise fashion. This alternative will be referred to in this report as the CAD alternative.

Development of alternatives

10. E. C. Jordan Company (1987) has revised the list of alternatives in its FS of remedial actions for the estuary. Technologies selected for incorporation into remedial alternatives are illustrated in Figure 5. The four NUS dredging and disposal alternatives described above have been combined and reduced into two alternatives.

a. Removal, disposal in shoreline or island CDFs, and water treatment.

b. Removal, temporary storage and/or disposal in shoreline CDFs, and disposal in CAD cells.

11. Shoreline disposal includes all identified CDFs adjacent to the estuary and harbor. Sites that are partially or totally in the water will be

considered nearshore sites, and those with a bottom elevation higher than mean high water will be considered upland sites. These two alternatives have passed the screening of alternatives step of the RI/FS process (Figure 2) and will be analyzed in detail by E. C. Jordan Company in accordance with the USEPA guidance (USEPA 1988). This EFS supports the detailed analysis of alternatives by providing information that may be used to evaluate the contaminant mobility, implementability, and cost for these alternatives.

12. This USACE investigation of these two alternatives considers the conceptual design of the components of the alternatives. Design options for CDF alternative a include lined CDFs, unlined CDFs, effluent, surface runoff or leachate treatment processes, and covers or caps. Upland and nearshore CDFs are evaluated. Design options for CAD alternative b are associated primarily with the sequencing of construction and the number of CAD cells and CDFs. Both of these alternatives involve dredging for removal of the contaminated sediment. The EFS evaluation of dredging equipment and controls during dredging has been documented in Report 10 and will not be repeated in this report.

Purpose and Scope

13. The purpose of this report is to evaluate conceptual dredging and disposal alternatives, including upland, nearshore, and CAD, for the Acushnet River Estuary. The evaluations are based on the results of sediment testing and sediment transport modeling. Generic requirements for the upland, nearshore, and CAD alternatives are described. Technical feasibility of conceptual design options is based on site availability, capacity, and characteristics and on sediment physical characteristics and dredged material settling behavior as defined by laboratory testing. Contaminant releases during dredging and disposal operations are estimated for each disposal option. Controls to minimize contaminant releases are based on the Management Strategy outlined by Francingues et al. (1985). A preliminary cost estimate for implementation of each option evaluated is also presented.

PART II: DESCRIPTION OF DISPOSAL OPTIONS

14. This part of the report will present generic descriptions of upland, nearshore, and CAD options. The objective of all of these options is to confine the dredged material solids in the disposal facility. Sizing of these facilities for dredged material storage follows a similar procedure for each option. This procedure is described in Engineer Manual (EM) 1110-2-5027 (USACE 1987). Principal differences in these three options are their geohydrology, sediment chemistry, carrier water removal, contaminant release rates, and contaminant pathways affected.

Upland Disposal

15. Upland disposal in a CDF involves the placement of dredged material in environments not inundated by tidal waters. Upland sites are normally diked confined areas that are hydraulically filled and retain the dredged solids while allowing the carrier water to be released (Figure 6). Upland sites, in the context considered by NUS Corporation (1984a), may also accept dredged material that has been dewatered near the dredge site and transported by truck or rail to an upland location at some distance from the site.

Upland CDF components

16. Nearly all upland disposal sites are diked areas. The major components of a diked CDF are shown schematically in Figure 6. The two objectives inherent in design and operation of containment areas are to provide adequate storage capacity for meeting dredging requirements and to attain the highest possible efficiency in retaining solids during the dredging operation (USACE 1987). Hydraulic dredging adds several volumes of water for each volume of sediment removed. The amount of water added depends on the design of the dredge, physical characteristics of the sediment, and operational factors such as pumping distance. The sediment and water are transported to the CDF as a slurry of water and solids. When the dredged material is initially deposited in the CDF, it may occupy several times its original volume. The settling process is a function of time, but the sediment will eventually consolidate to its in situ volume or less, if desiccation occurs. Adequate volume must be provided during the dredging operation to contain the bulked sediment.

17. Clarified water is normally discharged from the CDF over a weir. This effluent can be characterized by its suspended solids concentration and rate of outflow. Effluent flow rate is approximately equal to influent flow rate for continuously operating disposal areas. To promote effective sedimentation, ponded water is maintained in the area by adjusting the weir elevation. The thickness of the dredged material layer increases with time until the CDF fills with solids and dredging must cease. The dredged material will continue to settle and consolidate with time, potentially producing adequate volume for additional lifts of dredged material (USACE 1987).

Contaminant migration pathways

18. Migration pathways affected by upland disposal (Figure 7) include discharges to surface water during filling operations, releases from the settling and dewatering of the dredged material to surface water, rainfall runoff into surface water, leachate or seepage into ground water or surface water, volatilization to the atmosphere, and bioturbation. Bioturbation includes plant uptake and subsequent cycling through food webs and direct uptake by animal populations living in close association with the dredged material. Effects on surface water quality, ground-water quality, air quality, plants, and animals depend on the characteristics of the dredged material, management and operation of the site during and after dredging, and the proximity of the CDF to potential receptors of contaminants.

Physical/chemical changes

19. When dredged material is placed in an upland environment, drastic physical/chemical changes occur (Peddicord et al. 1986). As soon as the dredged material is placed in an upland CDF and exposed to the atmosphere, oxidation processes begin. The influent slurry water initially is dark in color and reduced, with little oxygen as it is discharged into the CDF from the hydraulic dredge. As the slurry water passes across the confined disposal site and approaches the discharge weir, the water becomes oxygenated and will usually become light gray or yellowish, light brown. The color change indicates further oxidation of iron complexes in the suspended particulates as they move across the CDF.

20. Once disposal operations are completed, dredged material consolidation will continue to force pore water up and out of the dredged material. The weir is usually designed and operated to provide drainage and removal of this water. This drainage water will continue to become oxidized and lighter

in color. Once the surfaced pore water has been removed from the surface of the CDF, the exposed dredged material will become oxidized and lighter in color. The dredged material will begin to crack as it dries out. Accumulation of salts will develop on the surface of the dredged material and especially on the edge of the cracks. Rainfall events will tend to dissolve and remove these salt accumulations in surface runoff. Certain metal contaminants may become dissolved in surface runoff.

21. During the drying process, organic complexes become oxidized and decompose. Sulfide compounds also become oxidized to sulfate salts, and the pH may drop drastically. These chemical transformations can release complexed contaminants to surface runoff, soil pore water, and leachate. Surface runoff testing of Acushnet River Estuary sediment demonstrated an increased mobility of cadmium, copper, and zinc after drying and oxidation (see Report 4). In addition, plants and animals that colonize the upland site can take up and bioaccumulate these released contaminants.

22. Volatilization of contaminants depends on the types of contaminants present in the dredged material and the mass transfer rates of the contaminants from sediment to air, water to air, and sediment to water. Release of the dredged material slurry above the water level in the CDF will enhance volatilization as the slurry impacts the CDF surface, creating turbulence and releasing dissolved gases. The transfer rate for organics such as PCBs from water to air is generally slower than from sediment to air (Thibodeaux, in preparation). Therefore, the inundated dredged material prior to dewatering is less likely to produce volatiles than the sediment as it dewaters and dries.

Nearshore Disposal

23. Nearshore disposal sites are CDFs located within the influence of normal tidal fluctuations. Dredged material is added to the diked area until the final elevation is above the high-tide elevation. The filling process and design for sediment storage and effluent suspended solids control are basically the same as described for upland disposal. Three distinct physicochemical environments exist at a nearshore site after filling (Peddicord et al. 1986).

a. Upland--dry unsaturated layer.

b. Intermediate--partially or intermittently saturated layer.

c. Flooded--totally saturated layer.

Nearshore CDF components

24. Nearly all nearshore disposal sites are diked areas. The major components of a diked nearshore CDF are similar to those shown schematically in Figure 6 for an upland CDF. The principal difference is that one or more sides of the nearshore CDF are constructed in the waterway, and the remaining sides are constructed on the shore, use the shoreline, or connect to the shore.

Contaminant migration pathways

25. Migration pathways affected by nearshore disposal (Figure 8) include all of the pathways discussed for upland disposal. Additional considerations for nearshore sites are soluble convection through the dike by tidal pumping in the partially saturated zone and soluble diffusion from the saturated zone through the dike. Ground-water seepage into or through the site can also be a factor affecting contaminant migration. These additional potential fluxes affect primarily the surface water pathway.

Physical/chemical changes

26. When material is initially placed in the site, it will all be flooded or saturated throughout the vertical profile. The saturated condition is anaerobic and reduced, which favors immobility of contaminants, particularly heavy metals. After the site is filled and dredging ceases, the dredged material above high tide begins to dewater and consolidate through movement of water downward as leachate, upward and out of the site as surface drainage or runoff, and laterally as seepage through the dike. As the material desiccates through evapotranspiration, it becomes aerobic and oxidized, mobilizing some contaminants as described previously. At this point the surface layer has characteristics like an upland site.

27. The bottom of a nearshore CDF below the low-tide or ground-water elevation remains saturated and anaerobic, favoring insolubility and contaminant attraction to particulate matter. After dewatering of the dredged material above the flooded zone ceases and consolidation of the material in the flooded zone reaches its final state, water movement through the flooded material is minimal and the potential for migration of contaminants is low.

28. The intermediate layer between the saturated and unsaturated layers will be a transition zone and may alternately be saturated and unsaturated as

the tide ebbs and floods (Figure 8). The depth of this zone and the volume of dredged material affected depend on the difference in tide elevations and on the permeability of the dike and of the dredged material. With low permeability material, the volume of CDF material impacted by this tidal pumping action is very small compared with the CDF total volume.

Contained Aquatic Disposal

CAD components

29. Contained aquatic disposal consists of excavation of a subaqueous pit within the estuary or waterway; controlled, accurate placement of contaminated dredged material in the bottom of the pit; and capping of the contaminated dredged material with a layer of clean, or less contaminated, dredged material. A CAD cell is not simply a variation of open-water disposal, but is an engineered structure, similar in some respects to a CDF. The sidewalls of the CAD provide lateral confinement of the dredged material slurry and provide the capacity for zone settling of the slurry. The cap is designed based on laboratory testing to determine the thickness necessary to prevent diffusion of chemical contaminants into the overlying water column and to prevent burrowing organisms from breaching the cap (see Report 6). Physical characteristics of the capping material should be resistant to erosion and resuspension under prevailing currents and waves at the site.

30. In some waterways, existing depressions or submerged dikes may be used in lieu of excavation for the pit. However, for CAD sites in the Upper Estuary of the Acushnet River, the pit must be excavated. This creates an additional handling problem since the top layer of excavated sediment in the estuary is contaminated, restricting its disposal or temporary storage.

31. Accurate placement of the contaminated material to the design elevation and capping to the required thickness is a critical component of the CAD operation. For hydraulic pipeline dredges, the submerged diffuser (see Report 10) is recommended for this part of the operation. After initial placement of the cap, the CAD site should be monitored for erosion or consolidation of the cap, bioturbation, and chemical migration. Maintenance of the cap, if necessary, would likely include placement of additional lifts of material until consolidation is complete.

Contaminant migration pathways

32. As dredged material slurry is pumped into a CAD cell, the slurry separates into two components: a turbid supernatant, or suspended fraction, and a dense, high-solids concentration suspension near the bottom of the cell. The dense suspension will undergo settling and expel pore water, carrying some suspended solids, particle-associated contaminants, and dissolved contaminants into the supernatant. The suspended material will either be carried away from the CAD cell by ambient currents, or will settle and deposit onto the dense suspension. The dense suspension will remain in the CAD cell as long as ambient currents are insufficient to entrain or erode the material. For the estuary sediment tested for this EFS, nearly all of the suspended material will escape the CAD cell (see Report 2).

33. Contaminant migration pathways for CAD are illustrated in Figure 9. During the dredging and disposal operation, surface water will be affected by the contaminated suspended fraction released as the slurry settles. However, in contrast to upland disposal, the contaminants will be maintained in their anaerobic condition for the most part, limiting the physical/chemical changes that increase solubility and mobility of many contaminants. Indigenous biological populations within the CAD cell will be covered or placed in direct contact with the contaminated dredged material. This local impact occurs for all other removal alternatives.

34. Once dredging is complete and the cap is in place, the dredged material will continue to consolidate and expel pore water beyond the boundaries of the contaminated material in the CAD. Downward and lateral convection of the pore water will affect ground water immediately adjacent to the CAD. However, the relatively static condition of the ground water beneath the estuary is not favorable to far-field transport away from the CAD area. Upward movement of this pore water must pass through the clean capping material to be released to the overlying surface water. Some of the pore water contaminants will be sorbed or attenuated as the pore water moves through the cap. The thickness of the cap is selected to minimize contaminants escaping through the cap and to prevent bioturbation through the cap into the contaminated material. It may be necessary to add additional clean material to the cap until the contaminated material reaches its final consolidation state and convective transport of pore water ceases. At this point, the contaminated sediment in the CAD cell has physical and chemical characteristics similar to

the original in situ sediment except that it is contained within the cell and isolated from the environment by the cap. Precipitation and infiltration have minor impacts on contaminant mobility, and volatilization is not a priority issue for the CAD alternative. A potential exists for long-term ground-water movement upward through the CAD where the ground-water elevation near the shoreline adjacent to the CAD cell is greater than the Upper Estuary elevation. This potential was not quantified by this study, but the impact on contaminant mobility will be limited by the low permeability of the consolidated dredged material. Quantification of this flux would require detailed geohydrological investigations beyond the scope of this study.

PART III: REVIEW OF SEDIMENT CHARACTERISTICS AND REMOVAL OPTIONS

Depth and Area To Be Dredged

35. The area and depth of the Upper Estuary to be dredged depend on the action level required to clean up the site to acceptable levels of PCB and heavy metals contamination. This action level is being evaluated, incorporating a contaminant fate and transport model coupled with a food chain model into an overall risk assessment. The acceptable level of contamination impacts the area and depth of sediment that must be removed from the Upper Estuary. In the Upper Estuary, including the adjoining wetlands, volumes at three depths are as follows:

PCB Concentration ppm	Volume, cu yd 0-1 ft	1-2 ft	2-3 ft	Total Volume cu yd	Cumulative Volume cu yd
>5,000	9,259	2,315	0	11,574	11,574
>500-5,000	99,537	18,518	2,315	120,370	131,944
>50-500	162,037	57,870	11,574	231,481	363,425
0-50	155,092	331,018	395,834	881,944	1,245,369
Total	425,925	409,721	409,723	1,245,369	

This table shows that if an action level of 50 ppm PCB were selected, removal of 343,107 cu yd of sediment would be required. Approximately 73 percent of this volume is in the top 1 ft. Only 4 percent is the 2- to 3-ft layer, but removal of 3 ft of material for all of the area more than triples the total volume. E. C. Jordan Company used an area of 264 acres for estimation of these volumes for the top 1 ft and 254 acres for the next 2 ft.

36. Report 10 recommended an operational method for dredging the upper 2 ft of the Upper Estuary. This method is to remove contaminated sediment in cuts approximately 1 ft depth. Because dredges cannot precisely cut a given thickness of material due to changing topography of the Upper Estuary bottom and varying surface-water elevations, a second pass of the dredge would increase effectiveness of the removal operation. The second pass is less important where the contamination is relatively low in the top 1 ft. This evaluation of disposal alternatives is based on removal of the top 2 ft of sediment from the Upper Estuary plus an additional 3,500 cu yd from the

2- to 3-ft depth in the hot-spot area (Grids J7 and I11 in Figure 10). Additional yardage from the 2- to 3-ft stratum where measurable contaminant concentrations are mapped could be dredged in lieu of the 1- to 2-ft stratum where contamination is very low without affecting the evaluation of a given design option. However, dredging 3 ft from the entire Upper Estuary cannot be implemented without the provision of additional CDF capacity.

37. Task 1 of the EFS included a topographic survey of the Upper Estuary and potential disposal sites in the Upper Estuary and upper harbor. Results of the survey (Appendix A) were used to compute the area to be dredged and the volume of dredged material resulting from a 2-ft depth of cut. Dredging is considered for removal of the contaminated sediment to the mean high tide elevation, selected as +4.0 above mean low water. This area is identified on the grid map for the Upper Estuary used in previous tasks for sediment sampling and characterization (Figure 10). The surface area within the +4.0 contour is approximately 187 acres. Removal of 2 ft of sediment from the entire area yields a volume of approximately 603,000 cu yd. Included in the +4.0 contour area is the developed area on the western shore of the Upper Estuary. This bank has been previously filled with riprap, construction debris, and other materials. A ground reconnaissance of the shoreline confirmed that this strip, ranging in width from 10 to 50 ft, cannot be removed with a hydraulic dredge. This estimated 50,000 cu yd of material may be removed by operating a clamshell dredge from the shore. The dredged material may be transported to the disposal site by truck.

38. This evaluation does not address removal of contaminated sediment above mean high water. The area affected by this assumption is primarily the wetlands on the Fairhaven side of the Upper Estuary. Because of the potential loss of environmental resources associated with this area, removal of contaminated wetland sediment seems unlikely. In the event site remediation requires removal of this sediment, mechanical removal from the land side at low tide should be considered to minimize the CDF volume required for disposal.

Sediment Characteristics

39. Sediments in the Upper Estuary have been characterized by a number of investigations. However, prior to the EFS, most of the studies evaluated only the surficial sediment, focused on the hot spot, and included limited

physical characterization of the material. Task 2 of the EFS collected sediment cores and analyzed these for chemical contaminants and physical (engineering) characteristics. Results of the initial characterization have been reported by Condike (1986). During the course of the FS, additional cores have been analyzed physically and chemically, providing additional information. Characteristics important to evaluation of CDF design options are summarized below.

Engineering characteristics

40. Engineering characterization data are summarized in Appendix B. The sediments to be dredged are a mixture of organic silts and clays with sand, sandy silts, and silty sands. The sediments are described horizontally in units corresponding to the grid cells and vertically in distinct sediment layers corresponding to sediment depths of 0 to 2 ft, 2 to 5 ft, 5 to 10 ft, and below 10 ft. The average sediment properties for these sediment layers are shown in Figure 11. Comparison of the data for the 0- to 2-ft depth layer, representative of the contaminated sediments, and the 2- to 5-ft depth layer, representative of the upper portion of the underlying clean sediments, indicates that these sediment layers are similar from a physical standpoint. At depths below 5 ft, the sediments are generally coarser, with sand predominant at depths exceeding 10 ft. Properties important to CAD and CDF design are in situ water content and percent sand. For the top 2 ft of sediment, the percent sand is 43 and the water content is 111 percent, which is equal to 660 g dry solids per litre.

Chemical characteristics

41. The PCB analyses of sediment cores for the 0- to 1-ft and 1- to 2-ft horizons are shown for the EFS grid system in Figures 12 and 13. Analyses were averaged for a grid where more than one core or analysis was available. These figures show that the density of analyses is much greater for the northern end of the Upper Estuary, particularly in the vicinity of the hot spot. Averaging all the concentrations available would skew the mean to the high side. To develop a general picture of the concentration differences by grid for the Upper Estuary and to estimate the overall PCB mass in the Upper Estuary, concentrations for grids with no data were manually estimated based on averaging available data for adjacent grids. Results of this procedure are shown in Figures 14 and 15. The PCB mass for each grid cell (Figures 16 and 17) was calculated based on the surface area to be hydraulically dredged for

each cell, water content of the sediment for each cell (Appendix B), and the PCB concentration assigned to each grid cell. Using this procedure, the total PCB mass in the top 2 ft for the Upper Estuary is estimated as 170,000 kg. The accuracy of this estimate is not easily established; however, this estimate is in the same order of magnitude as that of the E. C. Jordan Company (1987) PCB contouring effort.

42. Heavy metal concentrations in the Upper Estuary sediment exhibit less variability than PCB concentrations and can be described for the top 1- to 2-ft layer by averaging sediment cores analyzed by Condike (1986). Results of this evaluation are summarized in Table 1. Heavy metal concentration contours prepared by E. C. Jordan Company do not support changes in the proposed dredging scenario of removing the top 2 ft of sediment from the Upper Estuary, nor do they support separate consideration of controls for CDF design options.

Dredging Equipment

43. Evaluation of dredging equipment and dredging control technologies has been discussed in detail in Report 10. The conclusions of that report were that a small hydraulic pipeline dredge could be used to remove the contaminated sediment and that a submerged diffuser should be used to evenly distribute dredged material in the CDF or CAD. The dredge may be equipped with one of three types of heads: a conventional cutterhead, a horizontal auger or cutter, or a matchbox head. These dredgeheads will be evaluated by the proposed Pilot Study (Otis and Andreliunas 1987) that will provide additional data for selection, including production rate, sediment resuspension rate, removal efficiency, percent solids produced in the slurry, and costs. Evaluation of CDF/CAD design options will apply conservative estimates of these parameters, since no data are currently available to establish equipment- or site-specific values.

44. The nominal production rate for most small dredges is typically 80 to 100 cu yd (in situ sediment) per hour. Restrictions on operating time may be necessary to work with the tide for adequate operating depth and for minimizing transport of contaminants associated with suspended sediment. Dredges do not operate continuously because of downtime for positioning, maintenance, pipeline changes, etc. It is assumed that the dredge could work an

effective production time of 8 hr per day. This yields a production rate of 800 cu yd per day for a single dredge. Filling the CDFs at this relatively slow production rate will provide adequate time for settling and compression of the sediment solids in the CDF and limit the daily contaminant flux from the dredging and disposal operation. If the contaminant flux does not result in significant environmental impact, two dredges could operate simultaneously and pump to separate CDFs in order to reduce the overall cleanup time.

45. Transport of the dredged material slurry from the dredge to CDFs above the Coggeshall Street Bridge will be by floating pipelines. The pipeline must be carefully monitored during the operation so that pumping may be discontinued immediately if a major leak develops. Controls to reduce the potential for pipeline leaks include the use of continuously jointed pipe or enclosing the dredge pipeline in a larger pipe to contain any leaks. Transport to CDFs below the bridge will also be by pipeline, but it is recommended that the portion of the line south of the bridge be a fixed, overland installation with improved reliability and less likelihood for leaks directly into the estuary. Mechanically removed material may be transported to the nearest available CDF by lined and covered trucks.

PART IV: CONFINED DISPOSAL FACILITY EVALUATION

Background

Purpose

46. Evaluation of confined disposal facilities for the Acushnet River Estuary is Task 7, element 2, of the EFS. The purpose of this part of the report is to present technically feasible conceptual CDF designs based on results of previous tasks and elements of the EFS (see Report 1). The New Bedford Harbor FS considers CDF disposal as one alternative. Although there are several design options for this alternative, which could be considered as separate alternatives, they will be referred to in this report as "options" in order to avoid conflict with the FS terminology. These options include near-shore and upland disposal sites, effluent and runoff controls, and leachate controls. A number of combinations of disposal sites and control technologies are possible. The options discussed below are representative of the combinations available and the most likely scenarios for dredging and confined disposal given the current availability of CDF sites and anticipated requirements for contaminant removal from the Upper Estuary. Selection of a preferred design option is the responsibility of the USEPA and beyond the scope of the EFS.

Feasibility criteria for CDF evaluation

47. The scope of this evaluation of CDFs for engineering feasibility includes assessing the implementability, technical effectiveness, and cost for each design option. Implementability addresses the technical feasibility of constructing or operating the design option under site-specific conditions and the availability of specific disposal sites, equipment, materials, and/or conditions that may be necessary to implement the design option. Technical effectiveness is evaluated by determining the effectiveness of contaminant containment, short-term and long-term, for all pathways for each design option. Cost includes capital, as well as operation and maintenance costs. Costs will be compared with the technical effectiveness of the design options.

Potential CDF Sites

48. Detailed descriptions of the six CDF sites considered by the EFS are provided in this section. These sites were originally identified by NUS Corporation (1986) in its investigation and ranking of potential disposal sites and have been identified by E. C. Jordan Company as the most likely candidate sites for CDF disposal. The locations of these sites are shown in Figure 18, and preliminary layouts of the CDFs for each site are provided in Appendix A. Characteristics of potential CDF sites are summarized in Table 2.

Nearshore sites in the Upper Estuary

49. Four of the six sites, Nos. 1, 1A, 1B, and 3, are located in the Upper Estuary north of the Coggeshall Street Bridge (Figure 18). These sites are all nearshore sites requiring construction of an in-water dike. Borings and probes taken throughout the Upper Estuary show a significant layer of fine-grained material of low shear strength that in some locations extends to depths in excess of 10 ft. These soils generally consist of organic clays and silts and could have a marked effect on the stability of dikes and postconstruction settlement. Due to these conditions, a high-strength geotextile would initially be installed along the in-water dike alignments. Granular fill would then be placed in stages. This procedure would impact the length of the construction period due to the need to allow for consolidation of the weak foundation material between stages of fill placement and prior to filling of the site with dredged material.

50. One design option presented in this report considers liner systems at sites 1, 1B, and 3. An effective and moderately reliable liner system usually consists of a double liner with a leachate collection system above the top liner and a leachate detection system between the two liners (see Report 8). Construction of such a liner system will be difficult and expensive since these are in-water sites with poor foundation conditions. The construction procedure envisioned for these sites involves filling the area with hydraulically placed dredged material to an elevation above the high-water line. This would provide a more stable base out of the water on which to construct the liner and would allow operation of the leachate collection and detection systems.

51. Site 1 - western cove north of the Coggeshall Street Bridge. This site consists of a shallow cove on the west bank of the Acushnet River Estuary

approximately 1,000 ft north of the Coggeshall Street Bridge in New Bedford. The shoreline surrounding the cove is privately owned and undeveloped except for approximately 300 ft in the northeast corner that consists of a concrete wall fronting a parking area and a commercial facility. The site is close to both commercial and residential areas. A CDF constructed at this site would be approximately 22 acres in area and would have a volumetric capacity of approximately 270,000 cu yd of dredged material with dikes built to provide 8 ft of solids storage.

52. Site 1A - shoreline area south of site 1. This site would extend from the south side of the pilot study CDF to the Coggeshall Street Bridge embankment. The shoreline is undeveloped and abuts the parking area for a commercial complex. A gas station is located adjacent to the shoreline along what would be the southwest corner of the site. A CDF constructed in this area would cover approximately 4.5 acres and would contain approximately 30,000 cu yd of dredged material.

53. Site 1B - shoreline area north of site 1. This site is located approximately 5,300 ft north of site 1 along the New Bedford waterfront. The shoreline in this area is privately owned. A strip of land approximately 200 ft in width exists between the high-water mark and the line of buildings that extend from the north side of the cove described as site 1 to the northern end of the Upper Estuary. A CDF constructed in this area would cover approximately 10 acres and would contain approximately 90,000 cu yd of dredged material.

54. Site 3 - shoreline north of Coggeshall Street Bridge (Fairhaven side). This site is an open-water area just north of the Coggeshall Street Bridge on the Fairhaven side of the Upper Estuary. A CDF built in this location would be approximately 10.5 acres in surface area and would contain approximately 134,000 cu yd of dredged material. The waterfront in this area is privately owned and fronts several commercial activities.

Upland sites

55. The only upland sites identified as being available within the project area are located south of the I-195 highway bridges. These are identified as sites 6 and 12 in Figure 18.

56. Site 6 - Marsh Island. Marsh Island is a 30-acre peninsula located on the east bank of the Inner Harbor between the I-195 and Route 6 bridges in Fairhaven. The topography of the site is distinguished by bedrock outcrops on

the western end and approximately 5 acres of marsh in the northeast corner. The site was once used for the disposal of dredged material. Information obtained from subsurface investigations performed by E. C. Jordan Company found material onsite to be sand. Ground cover is predominantly marsh grasses with scattered brush and small trees. The entire area is privately owned and undeveloped except for a small operations building and two radio communication towers at the south side of the property. The site is remote from residential or commercial areas. A CDF approximately 9.5 acres in size could be constructed in the center of the area and would contain approximately 100,000 cu yd of material.

57. Site 12 - Conrail Railyard. The Conrail Railyard is located in New Bedford adjacent to Route 18 between I-195 and Route 6. The site is 22 acres in size and consists of an active and inactive railyard. The site is bordered on the west by a residential area and on the east by Herman Melville Boulevard. The harbor is located approximately 200 yd to the east of the site, making this the only site not adjacent to the water. The site is generally level, with a steep embankment defining its western boundary. Subsurface investigations conducted by E. C. Jordan Company found subsurface material to be sands and gravels. A CDF constructed on this site would contain approximately 325,000 cu yd. Hydraulic transport of dredged material to this site would require pipelines for influent and effluent to be routed under Herman Melville Boulevard and across the private property that separates this site from the harbor. The surficial soil layer at this site has been found to be contaminated with PCBs, which may require excavation prior to installation of a liner.

Design Requirements

58. Basic design requirements for storage of the dredged material and retention of solids generally control sizing CDFs for upland and nearshore sites. Requirements for volumetric storage, minimum surface area, effluent suspended solids, and weir length for CDF design options were calculated using the procedures described in EM 1110-2-5027 (USACE 1987). Design data for application of these procedures include sediment physical characteristics (Appendix B), dredge production rates, and laboratory settling test data. Settling data and example calculations are presented in Report 7.

59. What must be determined for this evaluation is the amount of sediment that can be contained in the available CDF volume and the optimum sequence of dredging and disposal operations to use the available volume. This determination will identify disposal site limitations and optimize use of available volume. The equations and techniques for the two approaches are the same except that the required approach is a trial-and-error procedure.

Flows and sediment concentrations

60. The volumetric flow rate for the dredged material slurry may be related to the dredge production rate, the in situ water content, and the solids concentration in the dredged material slurry. The production rate for the equipment selected has been established as 100 cu yd/hr for 8 hr/day production, and the average in situ water content is 111 percent (Appendix B). The solids concentration typically achieved by hydraulic pipeline dredge is in the range of 10 to 20 percent solids by weight. Engineer Manual 1110-2-5027 recommends a concentration of 150 g solids/ℓ for performing laboratory tests when no site- and equipment-specific data are available. This evaluation used a slightly more conservative solids concentration of 125 g/ℓ for the slurry. Dilution of the in situ sediment with carrier water from 660 to 125 g/ℓ produces a slurry flow rate 5.3 times the sediment production rate, i.e., 530 cu yd/hr, or 4 cfs. This flow rate will be used as the maximum instantaneous flow rate for the influent and effluent from the CDF. Average daily effluent flow based on a production rate of 800 cu yd/day and a 24-hr period is 4,240 cu yd/day, or 860,000 gal/day.

Features of available CDFs

61. Volumes. Table 2 lists the surface areas, volumes, and other information for the six CDFs considered for CDF design options. All CDFs will be designed to include a 2-ft ponding depth to allow for settling of suspended solids from the supernatant. Above the ponding depth is an additional 2 ft of freeboard. Sediment storage depths range from 8 to 11 ft. The ponding depth was assumed to be available for initial storage of clean material that will be placed as an initial surface cover.

62. Dikes. Typical cross sections of CDF dikes are illustrated in Figures 19-21. In-water dike construction for sites 1, 1A, 1B, and 3 requires staged construction with a base width of 200 ft and a maximum dike height of 12 ft above mlw. Figures 19 and 20 show site preparation requirements for

installation of a liner system for the in-water sites. Design features for the upland sites (Nos. 6 and 12) are illustrated in Figure 21.

63. Weir. Overflow from each CDF should be regulated by a rectangular-shaped weir. The height of the weir should be adjustable in order to selectively withdraw the clarified upper layer of ponded water during all phases of the operation. Lowering the weir after the CDF is filled will allow dewatering and consolidation of the dredged material. Weir length is designed to minimize the approach velocity to the weir and to limit the withdrawal zone, the area through which fluid is removed for discharge over the weir. The withdrawal zone should not be deeper than the ponding depth provided for clarification. Report 7 discusses weir design for primary and secondary CDF cells. For a flow of 4 cfs, a minimum weir length of 8 ft is required.

CDF design procedure for initial storage of solids

64. When sediment is dredged hydraulically, the additional water entrained by the dredge produces an increased volume of dredged material slurry. Soon after the slurry is released into the CDF, zone settling begins and an interface forms between the solids and supernatant. Particles in the solids layer touch each other in all directions and form a lattice structure that settles as a mass. Interparticle forces and the upward flow of water dispelled from the mass hinder settling. In a matter of a few hours, the zone settling phase is complete, and compression settling begins. During this phase of the process, the lattice structure of the solids is compressed and pore water is squeezed out. Although both of these processes are active in a CDF, most of the dredged material in the CDF is in compression. Design of a CDF for storage of solids using compression settling data usually controls the sizing of a CDF (Thackston, Palermo, and Schroeder 1988). Compression settling data for the Upper Estuary composite sample (Report 7) were used to determine the quantity of sediment that can be stored in the available CDFs.

CDF Design Options

65. Four design options were evaluated. Differences in these design options are due to liner provisions, sequence of filling, level of contamination placed in the various CDFs, and selection of CDFs where a choice is available. The design option descriptions presented below address the

implementability of the option. Cost and efficiency of contaminant containment will be addressed in relative terms in this section, but will be quantified in Appendixes C and D and discussed in Part VI.

CDF design option A

66. The CDF design option A uses CDF sites 1, 1B, 3, and 12, all of which would be unlined. The nearshore CDFs 1, 1B, and 3 will be constructed in the Upper Estuary prior to beginning dredging, and contaminated sediment beneath the in-water dikes will be covered with the dike fill. Table 3 shows the dredging sequence, average sediment characteristics, volume dredged, dredging rates, filling times, and dredged material volumes in the CDFs. Shoreline material within the nearshore CDFs would not be removed. Other shoreline material will be clamshelled and placed in CDFs 1 and 1B. Sites 1, 1B, and 3 are filled to capacity; CDF 12 is filled to 70 percent of capacity.

67. Advantages. Option A places the most contaminated material above the bridge and near its origin. Sediment placed in CDF 12 will be from the southern end of the Upper Estuary, and most of it will come from the 1- to 2-ft dredging depth, which will average less than 100 mg/kg PCB. It involves removing 484,326 cu yd of sediment, the smallest volume for the four options, and could be accomplished in approximately 5 years (see Figure C1, Appendix C) including 1 year for construction of the first one or two CDFs. It will also be the easiest option to implement because liners and leachate collection/treatment are not required. Construction and operation and maintenance (O&M) costs will be low.

68. Disadvantages. Construction of the in-water dikes on soft foundations will require staged construction and broad bases. Site 1B will be constructed near the hot spot. Dike filling will squeeze highly contaminated pore water out of the in situ sediment into the Upper Estuary. Containment efficiency within the CDFs will be lower than for lined alternatives, but this will be partially offset by reduced losses during dredging because of the lower volume. Monitoring the effectiveness of the system will require leachate and water quality monitoring. If the remedy proves to be less effective than required, future remedial action would require rehandling of the sediment and removal and disposal of potentially contaminated dike material.

CDF design option B

69. This option involves the same CDF sites as option A. The primary difference is in the sequence of dredging and the treatment of site 1B.

Site 1 will be constructed first, and sediment beneath the dikes of CDF 1B will be dredged and placed in CDF 1. Design information for solids storage in CDFs 1, 1B, 3, and 12 is presented in Table 4. Placement of the dredged material in the various CDFs from subareas of the Upper Estuary for this option is illustrated in Figure 22. This figure shows that the more contaminated sediment is placed in CDFs 1, 3, and 1B, which are in-water sites located above the bridge. Site 12, which is below the bridge, receives material from the lower part of the Upper Estuary where the sediment PCB concentration is less than 300 mg/kg (Figure 12). The sequence of operations for this option is shown in Figure C2. Total implementation time would be about 6 years. None of the sites would be lined for this option. In situ volume removed for this option is 514,259 cu yd, and dredged material storage volume required is 743,774 cu yd.

70. Advantages. The most contaminated material would be placed in CDF 1, and CDF 12 would receive the less contaminated material. Dike construction for 1B may be easier if the contaminated sediment is removed prior to placing the fill. The advantages of comparatively low cost for construction and for O&M are the same as for option A.

71. Disadvantages. Additional sediment volume must be dredged, compared with option A. Lack of leachate controls, difficulty in monitoring and guaranteeing contaminant containment, and the potential for costly future remedial action are also disadvantages.

CDF design option C

72. This option uses a combination of lined and unlined sites. Sites 6 and 12, upland sites, will be lined and will receive the more contaminated sediment. Nearshore sites 1 and 3 will not be lined and will receive the less contaminated material. The top 1 ft of sediment within the bounds of the nearshore sites will be dredged and placed in the lined sites. The mechanically removed shoreline material will be placed in CDF 1. Design data for this option are presented in Table 5. The dredge production rate for filling sites 6, 1, and 3 would be reduced to provide additional time for compression settling and to allow optimum use of the CDF volume. More than 6 years of dredging would be required to follow the sequence shown in Figure C3.

73. Advantages. This option provides secure storage for the most contaminated material and allows for collection and treatment of leachate. The nearshore (unlined sites) would contain moderately contaminated material.

This option avoids the contructability problems associated with lining the in-water sites and takes advantage of proven technology available for lining the upland sites.

74. Disadvantages. Highly contaminated material will be transported below the bridge, creating the potential for greater dispersion and down-harbor transport of any spills or leaks that develop during transport. Effluent from the CDF during the filling operation will also be released into the harbor rather than the Upper Estuary. Construction and O&M costs for the upland CDFs are high.

CDF design option D

75. Option D offers the greatest contaminant containment efficiency of the four options considered by this evaluation. All CDFs will be lined, and the top 2 ft of in situ sediment in the Upper Estuary will be dredged and placed in the lined facilities. Table 6 presents design data developed for this option, which requires construction of CDFs at sites 12, 6, 3, 1, and 1B. To reduce the volume required for initial storage, the dredge production rate would be reduced for all of the CDFs except site 12. The dredge would be scheduled to operate intermittently at full production rate to provide the storage time necessary for settling. Careful scheduling or a difference in sequencing could allow construction of two CDFs simultaneously and alternate dredging between the two sites in the same year. However, it is unlikely that the operation could be shortened to much less than the 12-year dredging period indicated by the construction sequence illustrated in Figure C4. Figure 23 shows the CDF destinations for sediment removed from Upper Estuary subareas. This sequence, which places the more contaminated material in CDFs 6 and 12, was selected because contaminated material from CDF sites above the bridge must be removed before lined sites can be prepared at these in-water locations.

76. Advantages. This option provides improved contaminant containment efficiency compared with other alternatives, assuming that leachate will be collected and treated. The reliability and effectiveness of the remedial action can be monitored, and future remediation is possible if monitoring detects an increase in mobility of contaminants. Placing the most contaminated sediment in CDFs 6 and 12 offers an advantage because the reliability and performance of lined and capped upland sites with leachate collection and treatment will be superior to the less reliable in-water sites.

77. Disadvantages. This design option is the most costly. Preparation of the in-water CDFs for installation of a double liner and leachate collection and detection system will require additional construction time. The success of this concept, in extremely compressible foundation material, has not been demonstrated and may present unforeseen problems for implementation. Of the four options considered, this option involves dredging the largest volume of material. The contaminant containment afforded by the lined CDFs will be partially offset by the increased contaminant losses during dredging of the additional material. The cost of this design option is much greater than option A, B, or C.

Control Technologies for CDF Options

78. To provide for increased environmental protection during and after disposal of dredged material in a CDF, additional control technologies may be added to or combined with the basic CDF design options described above. Table 7 lists the contaminant migration pathways and principal controls that will reduce contaminant releases to the specific migration pathway.

CDF effluent controls

79. Suspended solids removal. CDF effluent will contain suspended solids, particulate-associated contaminants, and dissolved contaminants that may be released to surface waters. One of the objectives of CDF design is to provide for settling of suspended solids. Therefore, all CDFs presented in this study include adequate ponding depth and surface area for effective gravity settling of suspended solids. Very efficient suspended solids removal by plain sedimentation has been demonstrated for dredging projects, particularly for those in saltwater environments. Palermo (1988) found that sediment retention efficiency in five saltwater disposal areas was above 99.7 percent.

80. Additional suspended solids removal can be achieved by adding polymers to the CDF effluent to effect chemical clarification (see Report 7 and Schroeder 1983). This technology has been proven at other dredging sites for suspended solids removal and for PCB removal as well (Hetling et al. 1979). All design options evaluated in this study include provisions for polymer addition at the weir from the primary CDF and for a secondary settling pond to remove the flocculated suspended solids.

81. Filtration is an effluent control technology for suspended solids removal that may be considered an add-on unit process. Filtration of CDF effluent may be accomplished by conventional filtration units used in the water and wastewater treatment industries or by pervious dikes or sand-filled weirs. To reduce O&M requirements caused by clogging of the filter, pervious dikes and sand-filled weirs use a coarse-grained filter media and may not provide the performance required for application to this project. For effective and reliable contaminant removal, filters selected for this project should be of the type used in industry, which have provisions for replacement and backflushing of the filter media. These filters typically use a porous medium specified for the particular stream to be treated and usually consist of sand and anthracite or coal. These filters perform well for influent suspended solids concentrations in the range of 100 to 200 mg/ℓ and achieve an effluent concentration of 1 to 10 mg/ℓ (USEPA 1985). Chemical clarification prior to filtration will assist in filtration of colloidal-size particles, which are too small to be trapped by the filter.

82. PCB removal. The processes evaluated by this study for further removal of dissolved PCBs are (a) carbon adsorption and (b) oxidation by ultraviolet light (UV) and hydrogen peroxide. Carbon adsorption following filtration is a demonstrated technology for PCB removal (Hand et al. 1978, Carpenter 1986). Additional design information for carbon adsorption will be developed during the New Bedford Superfund Pilot Study. The UV/peroxide treatment has proven effective in oxidizing many organic contaminants, including volatiles, and has good potential for effectively destroying PCB. The treatment offers the advantage of eliminating the need for handling and disposal of residual material, which is required for activated carbon. The UV/peroxide treatment was screened out by E. C. Jordan Company (1987) because of the resistance of PCBs to oxidation, potential toxic by-products of the process, and the limitations imposed on UV effectiveness by suspended solids and organic matter. Effectiveness of the process will be tested during the Pilot Study. Suspended organic matter and turbidity will be removed prior to the oxidation reaction by flocculation and filtration.

Surface runoff controls

83. Suspended solids removal. Suspended solids removal for surface runoff can be accomplished by the same processes as used to control CDF

effluent. These include sedimentation, chemical clarification, and filtration.

84. Ponding. Report 4 presents an evaluation of surface runoff from New Bedford sediment containing 80 ppm PCB. The evaluation demonstrated that surface runoff from wet, unoxidized material, such as would be initially placed in the site, was contaminated primarily by particulate-associated contaminants and that removal of particulates would remove 90 to 99 percent of all contaminants in surface runoff. Maintaining a ponded water volume above the sediment layer in the CDF will reduce erosion and resuspension of sediment and provide opportunity for sedimentation. The secondary settling pond will provide additional capacity for sedimentation. During the time that dredged material is being discharged into the CDF, precipitation adds to the CDF effluent volume, but has little impact on contaminant concentration in the effluent.

85. Surface runoff treatment. Surface runoff treatment beyond suspended solids removal can be accomplished by the same processes as for CDF effluent. If CDF effluent treatment is provided, the same control measures could be continued for surface runoff treatment. The need for this treatment could occur in the event that the CDF is dewatered prior to establishment of an adequate cover.

86. Surface cover. The best control technology for preventing contaminant losses via surface runoff once the CDF is filled is to cover the contaminated dredged material with a cap that prevents contact of precipitation and runoff with the contaminated material and minimizes infiltration of this water into the contaminated zone. All CDF sites will be covered with 2 ft of clean, hydraulically placed dredged material prior to promoting drainage to remove ponded water and dewater the surface layer. After consolidation of the contaminated dredged material and the clean dredged material cap to the point that earthmoving equipment can work on the site, a layer of low-permeability, clean fill should be placed on the site, graded, and compacted. On top of this layer will be placed a flexible membrane cover and a topsoil suitable for supporting vegetation. A profile of the recommended surface cap is shown in Figure 24.

Leachate controls

87. Leachate from a CDF for dredged material is produced by three potential sources: pore water for the dredged material placed in the site,

net precipitation percolating through the dredged material, and ground water or estuary water contacting the dredged material as a result of tidal pumping. Drainage of pore water and percolation of precipitation occurs for all types of CDF sites. Ground-water percolation through a site can occur for a site constructed below the water table, and tidal pumping may occur for nearshore CDFs where dredged material is placed below the high-tide elevation. The upland CDF sites are all constructed above the water table and should not be in contact with ground-water movement.

88. The time frame during and immediately after CDF filling represents the greatest potential for leachate flow because it occurs during the maximum head above the CDF bottom and when the dredged material permeability is greatest. As the dredged material consolidates, water is expelled from the dredged material, and the permeability of the fine-grained sediment is reduced (see Appendix D). Not all consolidation pore water expulsion produces leachate. Some of this water is expelled at the surface and evaporates or is drained from the site as CDF effluent.

89. Once the final state of consolidation is reached, net precipitation becomes the primary source of leachate from the site. Evaluation of leachate quality for New Bedford sediment (Report 5) showed that freshwater washout of salinity from the sediment increased the rate of contaminant desorption from the sediment and increased the concentrations of PCBs and heavy metals in leachate. Therefore, all sites should include controls to reduce the long-term percolation of precipitation through the site.

90. Surface cover. All CDFs should include surface covers as a control measure for leachate. The cover or cap should be designed to prevent or minimize surface water infiltration into the contaminated dredged material. The cover for leachate control will be in addition to the clean dredged material cover recommended for control of surface runoff. Surface covers for leachate control cannot be installed until the final state of consolidation of the hydraulically placed dredged material layers has been achieved.

91. As shown in Figure 24, the cover should include at least three layers. On top of the clean dredged material will be a layer of fine-grained material that can be compacted to provide a firm, relatively impermeable foundation for the primary hydraulic barrier, the second layer. The compacted material may be produced by grading and shaping the top layer of dredged material, or an additional layer of fill material may be required. Recommended

for the hydraulic barrier is a flexible membrane material such as high-density polyethylene or similar material. The final layer is a 2-ft layer of topsoil, which should be graded for drainage and vegetated with selected shallow-rooted plant species or covered with additional capping material or paving for a particular intended use.

92. Covers are a proven technology and have been successfully implemented at sanitary landfills and hazardous waste disposal sites. Covers have not been routinely used for dredged material sites, but with adequate design and construction techniques and suitable materials, application of cover technology to the CDFs proposed for this project is feasible. The greatest concern for reliability of the cover system is root penetration, consolidation of underlying material, and disturbance at the surface by man.

93. Liners. The second control measure that may be applied to a CDF for leachate is to line the bottom and sides of the CDF. Liners are designed to prevent movement of leachate out of the site by providing an impermeable barrier to leachate flow. Liners control leachate from all of the sources discussed above, i.e., pore water drainage, precipitation, and ground-water or tidal flow. Liners must be installed as a component of CDF construction.

94. A reliable liner system for hazardous waste sites has been defined by the USEPA as a multilayer system consisting of a double-membrane liner system with leachate collection below the top membrane liner and leachate detection between the top and the bottom membrane liner (Figure 25). The foundation of the site should be of compacted, low-permeability soil. A flexible membrane liner is placed on top of the foundation. A drainage layer between the two membranes is monitored to detect the need for remedial action if the top liner fails. Leachate passing through the dredged material is collected above the top liner to minimize the head impacting on the liner system. Leachate collection provides the opportunity to treat the contaminated leachate from the dredged material.

95. Reliable long-term performance of liner systems is subject to a number of failure mechanisms (see Report 8). Technology and construction techniques are improving, and the double-liner system with leachate collection and detection provides the redundancy to monitor the performance of this leachate control technology.

96. Implementation of liner systems at upland sites is possible, although expensive. Construction of a liner system at nearshore or in-water

sites presents a unique and difficult construction requirement. Membrane liners require dry conditions to allow construction of leakproof seams and to prepare the subgrade for proper installation of the liner. Flexible membrane liners may be seamed on dry land or a barge and then placed in the nearshore disposal facility. However, depending on the size of the CDF, this may require a costly effort to properly place the liner. Liners for dike faces have been seamed and installed from barges with varying degrees of success. The changing environment, such as fluctuating water levels, tidal pumping, and gas-producing organic bottom sediments, and the weak foundation for available nearshore CDFs will also place physical stresses on flexible membrane liners. Leachate detection for an in-water system would be meaningless.

97. Option D, which includes lined CDFs at nearshore sites, requires filling the nearshore sites with clean fill to above the high-tide elevation to provide the foundation for the liner system. Using such a construction sequence will require much additional time to allow for consolidation of the filled foundation to the point that it will support the liner system and subsequent contaminated sediment and cover system. This technology for nearshore sites ranks lowest in implementability for the control technologies considered.

98. Leachate treatment. Leachate treatment is possible for CDFs constructed with liners and leachate collection systems. It is assumed that a remedial action requiring leachate treatment would also require effluent treatment for dissolved contaminant removal. Leachate could be treated in the same system while contaminated effluent is being generated. Long-term leachate controls require that a leachate treatment system be in place for at [illegible]t 10 years after filling. However, the volume for treatment would [illegible]ease as the site ages and the drainable pore water is removed.

[illegible]lization

99. The volatilization pathway for loss of PCBs becomes very important [illegible]taminated sediment is exposed to the air and allowed to dewater and dry [illegible]aux, in preparation). Transport by this pathway can be minimized by [illegible]ng saturated conditions and a layer of water on top of the contami[illegible] [illegible]dged material while it is being pumped into the site. Prior to [illegible] the ponded water, a layer of clean dredged material should be placed [illegible] the CDFs. Further protection from volatilization losses will be [illegible] a relatively impermeable, permanent surface cover.

Plant and animal uptake

100. Surface covers are also recommended as the means for preventing direct contact of plants and animals with the contaminated dredged material. Long-term management of the site will require maintenance of the cover and controls for use of the site that prevent breach of the cover by human activities or uncontrolled vegetation.

Selection of CDF Design Option and Control Technology Schemes

101. This section will discuss the combinations of CDF design options (A, B, C, or D) and control technologies (Table 7) that will logically meet a restriction on contaminant release for a particular migration pathway. These schemes represent a number of feasible alternatives that will achieve a level of contaminant migration at an associated cost. Cost versus contaminant containment will be discussed in Part VI. Since most CDF design options and control technologies address more than one pathway, separate schemes for each pathway will not be listed.

102. Table 8 presents the CDF schemes selected for detailed evaluation and ranking in this EFS. Options A1 and B1 represent the schemes that are the simplest and easiest to implement. Control technologies applied for these schemes are limited to chemical clarification and a surface cover. These schemes provide minimum protection for surface-water impacts from CDF effluent, control of surface-water runoff impacts on surface waters, control of precipitation infiltration through the CDF, and control of PCB volatilization. Options A2 and B2 include chemical clarification, surface cover, and filtration of CDF effluent. This provides for additional removal of suspended solids and associated contaminants that would otherwise be released to the surface-water pathway. Options A3 and B3 provide the same controls as A2 and B2 with the addition of treatment for removal of dissolved PCBs, effecting further protection for surface waters.

103. Options C1 and D1 include all effluent controls and surface covering plus additional leachate control. Option C1, as described in the initial development of CDF design option C, includes lining the upland sites for the most contaminated sediment and placing the less contaminated sediment in unlined nearshore sites. Option D1 proposes installation of liner systems for all CDFs. Both C1 and D1 would provide for effluent and leachate

treatment since it is assumed that, if there is a need to expend funds for leachate controls, effluent controls would also be required.

Monitoring Requirements

104. Implementation of the CDF alternative will require short-term monitoring to ensure protection of the environment during dredging and disposal operations and long-term monitoring to assess performance of the remedial action. Short-term monitoring should include water quality monitoring in the estuary and monitoring of components of the dredging and disposal system. Long-term monitoring will involve sampling and analysis of ground water around the CDFs, periodic evaluation of surface runoff from the CDFs, inspection of the surface cover integrity, and water quality monitoring in the vicinity of the CDFs.

105. The water quality evaluation would include appropriate hydrologic, chemical, and biological data collection to assess the contaminant releases associated with implementation of the remedy. Effectiveness of the CDF and associated effluent treatment processes for meeting performance objectives would be evaluated by measuring flow and chemical characteristics for the effluent released to the estuary and for intermediate points within the treatment process scheme. Results of the water quality monitoring and CDF monitoring would provide information for control of the operation to meet allowable contaminant loads and release rates.

106. A major monitoring operation for implementation is sampling after dredging to determine if the desired contaminant level in the remaining sediment has been achieved. Sediment sampling after the dredge should be an integral part of the sediment removal activity.

107. Air quality monitoring may also be required. The Pilot Study will give an indication of the importance of this pathway during the dredging and filling operation. This information can be applied to development of an appropriate air monitoring program.

PART V: CONTAINED AQUATIC DISPOSAL EVALUATION

Background

108. The second alternative being considered by the FS for disposal of PCB-contaminated sediments from the New Bedford Upper Estuary is contained aquatic disposal. This disposal alternative involves the dredging of the contaminated sediments, placement in preexcavated subaqueous pits, and capping with clean sediment.

109. Contained aquatic disposal is similar to level-bottom capping but with the additional provision of some form of lateral confinement to minimize spread of the materials. Level-bottom capping may be defined as the placement of a contaminated material at an open-water disposal site on the bottom in a mounded configuration and the subsequent covering of the mound with clean sediment. Level-bottom capping is a dredged material disposal alternative routinely used in the US Army Engineer (USAE) Division, New England (Morton, Parker, and Richmond 1984; Truitt 1987a) and the USAE District, New York (O'Connor and O'Connor 1983, Mansky 1984, Truitt 1987a). The CAD alternative has been successfully used in Rotterdam Harbor, the Netherlands, for the placement of highly contaminated sediments (d'Angremond, de Jong, and de Waard 1986) and has been demonstrated or proposed for a variety of disposal conditions (Truitt 1986, Environmental Laboratory 1987, Palermo et al. 1989).

110. In an earlier Feasibility Study for the Upper Estuary (NUS Corporation 1984b), CAD was evaluated in general terms. Six subaqueous cells in the Upper Estuary and temporary confined disposal facilities were envisioned. However, no detailed evaluations of technical feasibility were conducted. Also, the project conditions with respect to volumes of sediment to be removed, etc., are being reevaluated.

111. The CAD option for the Upper Estuary as presently proposed would involve use of a small hydraulic dredge for removal of the sediments. The dredged material slurry would be pumped directly into preexcavated CAD cells. Following placement of the contaminated material in a CAD cell, the cap material would be dredged with the same equipment and placed over the contaminated sediments to fill the CAD cell. A submerged diffuser would be used to control the placement of material and minimize contaminant release during placement. This concept is illustrated in Figure 26. This sequence of operations would

be repeated for the required number of CAD cells until the required volume of material was dredged and capped. Initial removal of some material with placement in a CDF would be required to create the first excavated CAD cell.

112. The CAD operation successfully executed at the First Petroleum Harbor project in Rotterdam, the Netherlands (d'Angremond, de Jong, and de Waard 1986) is similar to the proposed CAD alternative for the Upper Estuary. The Rotterdam project involved multiple CAD cells, with material excavated to cap a cell forming the excavation for the subsequent cell. A matchbox dredge was used for this project to minimize sediment resuspension, and a submerged diffuser was used for hydraulic placement of the material in the CAD cells. The sediment dredged was a highly contaminated silt with average grain size of 7 μ. Sediment resuspension was confined to the immediate vicinity of the dredge and diffuser. The volume initially occupied by the sediments in the cell was approximately 1.3 times the in situ channel volume prior to dredging.

Purpose

113. This part of the report evaluates the technical feasibility/implementability of CAD as a disposal alternative for the Upper Estuary site and defines the design requirements for CAD. It contains descriptions of the equipment and techniques for dredging and placement, layout and sizing of CAD cells, required cap thicknesses, estimates of contaminant releases associated with CAD, and monitoring requirements.

114. The general approach for CAD in the Upper Estuary involves "turning over" the surficial layer of contaminated material. To accomplish this, disposal of an initial portion of the material in a CDF is required to allow construction of the first CAD cell in a clean area of the channel bottom. The following evaluation of the engineering feasibility of CAD was conducted using general procedures found in Truitt (1987b).

Engineering Feasibility Determination

115. The steps used to determine the engineering feasibility of CAD for this project are as follows:

a. Identify appropriate equipment and placement techniques for CAD for the anticipated site conditions.

b. Determine acceptable location of CAD cells.

c. Determine required cap thickness using appropriate capping effectiveness testing procedures.

d. Determine the volumetric sizing requirements for the CAD cells and the corresponding requirements for use of CDFs.

e. Determine the potential degree of contaminant containment effectiveness for the CAD alternative.

f. Determine appropriate monitoring requirements and remedial action.

g. Estimate cost of the CAD alternative.

Steps a through d establish the implementability of the alternative, step e establishes the technical effectiveness of the alternative, and step f provides cost for the engineering feasibility evaluation.

Criteria for Determining Implementability and Technical Effectiveness

116. A CAD alternative that could be successfully implemented and technically effective for the Upper Estuary should meet the following criteria:

a. The material can be placed and capped within areas available for CAD cells.

b. The capping thickness required to isolate the contaminated material from the environment in the long term can be successfully placed and that thickness maintained.

c. Estimated contaminant releases during CAD operations downstream of the Coggeshall Street Bridge are within criteria to be established by the USEPA.

Pilot Study

117. A pilot study and associated monitoring program will be used to confirm the criteria listed above. The pilot study includes construction of a CAD cell, placement of contaminated material using hydraulic dredges and diffusers, and capping with clean material. It is scheduled for a period of approximately 3 months, beginning November 1988.

CAD Site Selection and Description

Site description

118. The Upper Estuary encompasses approximately 187 acres. The bottom depths are generally 1 to 3 ft below mlw elevation with the exception of a channel in the lower portion of the Upper Estuary, which varies from 7 to 14 ft deep. The sediments to be dredged are generally silts and clays with significant fractions of fine sand. Detailed descriptions of the site geometry, hydrodynamics, and sediment properties are found in Appendix B and Report 2.

119. A grid cell system was established throughout the Upper Estuary for purposes of reference and control (Figure 27). Maps showing water depths in the Upper Estuary are included in Appendix A.

Selection of CAD site within the Upper Estuary

120. Potential locations for CAD cells were considered only within the area of the Upper Estuary. This restriction provides the following advantages:

- a. All contaminants from the cleanup area would be disposed within the area, minimizing the potential contamination of cleaner areas during the placement operation.
- b. The resulting bottom geometry of the Upper Estuary would be altered to a lesser degree than if large volumes of material were disposed outside the area.
- c. Materials used for capping could be obtained onsite at lower cost if the CAD operation proceeded in a phased sequence.
- d. Pumping distances for placement of the contaminated material would be within the capability of small hydraulic pipeline dredges, avoiding the need for booster pumps.

Influence of currents

121. Currents within the Upper Estuary vary with tidal cycle but are generally less than 1 fps. This range of current velocities, coupled with the shallow water depths in the nonchannel portions of the area, will not influence the point of placement of material within excavated CAD cells. This is further reinforced with use of a submerged discharge, as discussed in the section on equipment and placement techniques.

122. The major influence of currents at the site is the potential for resuspension and transport of the contaminated material right after placement in CAD cells, but before capping. Immediately following placement with a

hydraulic dredge, the material is still in a slurry condition. Model studies (see Report 2) indicate that current velocities associated with a 5.5-ft spring tide exceed the acceptable values for shear stress for the newly deposited contaminated material. A map indicating zones that are unacceptable for location of CAD cells due to excessive current velocities and associated erosive forces is shown as Figure 28.

Influence of bathymetry

123. Since the bottom bathymetry of the Upper Estuary is essentially flat, no restrictions on location or construction of the CAD cells or placement of materials for CAD are evident with respect to bathymetry over most of the area. An exception is the immediate area of the channel. The existing channel side slopes would potentially present stability problems during CAD cell construction. Also, restoration of the original channel geometry following CAD construction would be difficult. For these reasons, location of CAD cells within and immediately adjacent to the existing channel was not considered. The channel areas considered unacceptable for CAD cell location due to sloping bathymetry fall within the exclusion zones due to currents previously described. Similar stability problems must be considered in areas immediately adjacent to the shoreline.

Influence of water depth

124. Water depths in the nonchannel areas of the Upper Estuary vary from 1 to 3 ft below mlw elevation. Considering that the CAD cells will be excavated several feet below the existing bottom and only partially filled prior to capping, the contaminated material will be placed in the cells at water depths of approximately 5 to 10 ft. Such shallow depths of placement have short-term benefit. The shallow depth, coupled with use of a submerged discharge point, will minimize additional entrainment of water during the placement process. If the material were allowed to fall through the water column, additional water would be entrained in the dredged material slurry and could potentially become contaminated.

125. In the long term, the shallow water depth is generally a disadvantage from the standpoint of erosion, since erosive forces during storm events are stronger in shallow water depths. However, no significant erosion of in situ sediments in the Upper Estuary has been observed due to past storms. In fact, the hydrodynamics of the Upper Estuary indicates that the

entire area is depositional in nature (see Report 2). Further, the capping material is of coarser grain size than the existing bottom sediments.

Designation of acceptable areas for CAD cells

126. Areas deemed unacceptable for locations of CAD cells due to excessive bottom slopes or currents are indicated in Figure 28. The remaining areas include the northern half of Upper Estuary, excluding the narrow channel immediately below the Wood Street Bridge, and the cove areas within the lower portion of the Upper Estuary. Since the cove areas are the prime candidates for CDFs required for implementation of the CAD alternative, the only feasible area for location of a CAD cell of practical size is within the upper portion of the Upper Estuary.

127. Based on the above considerations, an acceptable area for locating a CAD cell configuration was selected (see Figure 29). This is the only area available when considering erosion rates and the potential for excessive loss of material during placement. The irregular boundary was selected to encompass the maximum possible area while allowing for a 100-ft buffer from the shoreline assumed to be appropriate for stability purposes.

Selection of Capping Material

128. The CAD cells must be excavated within the clean sediment layers in the upper portion of the estuary. The clean sediment removed by the CAD cell excavation is the logical source of material for use in capping the cells. Since a portion of the volume of underlying clean sediments used for the cap will be taken from sediment depths exceeding 5 ft, the cap for the CAD cells generally will be coarser than the contaminated sediment to be capped.

Equipment and Placement Techniques

129. Basic considerations in planning a CAD operation include the equipment and techniques required to accomplish the dredging, transport, and placement of the contaminated dredged material and capping materials.

Dredging equipment
for contaminated material

130. An 8-in. hydraulic pipeline dredge will be used for removal of contaminated sediments. A production rate of approximately 100 cu yd per hour (in situ yards) is anticipated for this dredge. Assuming use of a single dredge and an effective operating time of 8 hr per day, the total production for CAD operations would be approximately 800 cu yd per day.

Transport and placement
method for contaminated material

131. Direct pipeline placement of the contaminated material within the excavated CAD cells is the logical transport method for CAD at this site. Use of a submerged diffuser (see Figure 30) for placement is considered a necessary control measure to reduce water column resuspension and placement velocities. The submerged point of discharge physically isolates the contaminated material from the water column. The diffuser reduces the pipeline exit velocity and radially discharges the material at the bottom of the CAD cell. The effectiveness of the diffuser will be monitored as a part of the pilot study. The diffuser design will be in accordance with specifications developed during the Corps of Engineers Dredged Material Research Program (DMRP) (Neal, Henry, and Greene 1978).

Dredging equipment
selection for capping material

132. Use of small hydraulic dredging equipment (the same equipment as for the contaminated material) is the most desirable technique for excavation of the CAD cells and placement of the capping sediment. The operating water depth in bottom areas from which capping sediments will be dredged will be increased by 2 ft due to previous removal of contaminated sediments. However, this operating depth is still too small to consider any large hydraulic dredge type or mechanical dredge.

133. One of the most important considerations in selecting a dredge type for the capping sediments is the potential for displacement and resuspension of previously placed contaminated material in the CAD cells during placement of the cap. Hydraulic placement of the cap material using a small hydraulic dredge and the submerged diffuser will reduce the potential for displacement and resuspension.

Transport and placement
method for capping material

134. The same considerations apply for transport and placement of the capping sediment as for the contaminated sediment. Direct pipeline transport with the submerged diffuser will tend to isolate sediment resuspension from the water column. The reduced exit velocities associated with the use of a diffuser will reduce potential resuspension of contaminated material. The radial configuration of the diffuser, coupled with a moving discharge location, will allow the gradual buildup of the layer of capping material. This will minimize the potential displacement of the contaminated material.

Navigation and positioning

135. Precise control of the location of the dredgehead for excavation and of the diffuser for placement will be critical for successful CAD operations. The relatively narrow channel width and shallow water depth present no unusual limitations on the attainable accuracy of onboard electronic horizontal positioning equipment. Another option is to position control rods by conventional survey techniques.

Capping Thickness Requirements

136. Capping effectiveness tests were conducted to determine the minimum cap thickness necessary to chemically isolate the contaminated material from the overlying water column. These tests are described in detail in Report 6. The test results indicated that a cap thickness of 35 cm is sufficient to provide chemical isolation. Additional cap thickness is necessary [illegible] prevent penetration of burrowing organisms into the contaminated layer. An [illegible]uation of the potential communities that may recolonize the site has [illegible]rmined that the burrowing depth of organisms of concern is 20 cm or less. [illegible]fore, a minimum cap thickness of 55 cm is needed for chemical and [illegible]gical isolation.

137. An initial cap thickness of 4 ft should be specified as an opera[illegible] requirement. Assuming that consolidation of the cap will be approxi[illegible]ft, this will result in a final cap thickness of approximately 3 ft. [illegible]ational requirement will provide added protection and allow for [illegible] variations in the applied cap thickness.

Development of CAD Options

Use of CDFs

138. In the earlier Feasibility Study (NUS Corporation 1984b), the entire Upper Estuary was assumed available for construction of CAD cells. The acceptable zone for location of CAD cells determined for this study constrains the use of CAD for disposal of all potentially removable material. The options as developed are therefore a combination of CDF/CAD.

139. For the CAD alternative, use of CDFs is required to allow construction of CAD cells. The CDFs are necessary to store contaminated material from the CAD cell location, allowing excavation of the CAD cell in the clean sediment layers. Also, CDFs are necessary for temporary storage of clean material from the CAD cell excavation, which would later be used to cap the CAD cell. Some clean material would also be used to restore reaches of the Upper Estuary to their original predredging geometry.

140. The sizing and configuration of CAD cells was determined assuming that the use of permanent CDFs should be kept to a minimum. However, disposal of the contaminated materials of higher PCB concentration in CDFs would provide a higher level of contaminant containment during and following placement. Therefore, three CAD options were developed, to incorporate the minimum construction and use of CDFs consistent with a given level of containment.

141. Since selection of a CAD alternative would mean that a higher level of contaminant release during placement was acceptable, the use of liners in CDFs to prevent comparatively small leachate release rates would be unwarranted. Therefore, all CDFs were assumed to be unlined for the CAD options.

142. Six potential CDFs have been identified in the vicinity of the Upper Estuary. The locations of the sites are shown in Figure 18. Site characteristics are summarized in Table 9. In selecting specific CDFs for the CAD options, use of sites above the bridge within the Upper Estuary was preferable. However, use of sites below the bridge for temporary storage of clean material proved to be necessary.

Description of CAD options

143. Three CAD options were developed consistent with minimal use of CDFs and placement of more contaminated materials in CDFs. Brief descriptions of the options are as follows:

144. CAD option A (three permanent CDFs). This option involves placing the more contaminated materials from the northern half of the Upper Estuary (including the hot spot and adjacent areas) into CDFs 1, 1A, and 3, which would remain as permanent disposal sites. Contaminated material from the lower half of the Upper Estuary would be placed and capped in a CAD cell that would be filled and capped in two sections. Excess clean material from the CAD cell excavation would be temporarily stored in CDFs below the bridge and later removed for capping and restoration of channel areas. Volumetric capacity temporarily required below the bridges would be approximately 238,000 cu yd, which could be accommodated within site 12.

145. CAD option B (two permanent CDFs). This option involves placing the more contaminated material (essentially the hot spot and adjacent areas) into CDFs 1 and 1A, which would remain as a permanent disposal site. Contaminated material from near the Wood Street Bridge and from the lower half of the Upper Estuary would be placed in a CAD cell that would be constructed, filled, and capped as a single cell. Excess clean material from the CAD cell excavation would be temporarily stored in CDFs below the bridge and later removed for capping and restoration of channel areas. Volumetric capacity temporarily required below the bridges would be approximately 558,000 cu yd, which would require use of a combination of sites 6 and 12.

146. CAD option C (no permanent CDF). This option involves placing all contaminated materials in a CAD cell. However, the option was found to be infeasible unless additional CDF capacity for temporary use could be located within pumping distance of the project area. Site 1 would be used for temporary storage of contaminated materials to allow construction of the CAD cell. Excess clean material would be stored and later removed from CDFs below the bridge, as described for previous options. The CDF 1 materials would be dredged during the CAD filling process. No CDFs would remain as permanent disposal areas. Volumetric capacity temporarily required below the bridges is approximately 1,060,000 cu yd, which exceeds the capacity of CDFs identified to date. Material available for channel restoration would restore Area C plus essentially fill the central channel to the adjacent mudflat level. As an alternate, Area A could be restored with a portion of the excess material.

Sizing and Locating CAD Cells

147. A major factor in the feasibility of CAD was determination of the volumes required for both CDFs and CAD cells in "turning over" the Upper Estuary sediments. Considerations in determining the sizing and configuration of the CDFs and CAD cells required are discussed in the following paragraphs.

Sizing procedures

148. When a given volume of in situ sediment from a channel is dredged hydraulically, the volume occupied in a disposal site (either CDF or CAD cell) is greater because of water added during the dredging process. The volume change is generally a function of time required for dredging, settling characteristics of the material, percent coarse-grained material, and water content of the in situ sediment. For this CAD evaluation, volume changes were calculated using procedures for disposal area sizing in EM 1110-2-5027 (USACE 1987). The CAD cells will be oversized to accommodate fluctuations in bulking and volumes of material to be filled because, once a CAD cell is excavated and filling with contaminated material begins, there is no provision for permanently expanding its CAD capacity.

CDFs for use with CAD options

149. For the CDFs used with the CAD options, the dike center lines follow those shown in Appendix A, providing the storage volumes shown in Table 9. The CDFs that remain as permanent disposal sites will, of course, be filled to above mean high water elevations (see Figures 19-21).

150. The sizing calculations for CDFs were made assuming that CDFs would be operated with a 2-ft freeboard and 2-ft ponding depth during filling for contaminated material. The ponding depth was assumed to be available for initial storage of clean material that would be needed to place a surface cover. The minimum final surface cover thickness of clean dredged material for a CDF used for permanent storage of contaminated material was assumed to be 3 ft. The surface cover thickness initially placed was 4 ft, allowing for 1 ft of surface cover consolidation. On top of the dredged material cap will be placed a flexible membrane cover system, as shown in Figure 24.

Excavation of shoreline material

151. For all CAD options, contaminated material to be dredged adjacent to the shoreline was assumed to be excavated using mechanical equipment operating from shore. Enclosed clamshell buckets would be used to reduce

spillage even though the majority of the excavation would be timed to occur in the dry during low tide. Shoreline material was assumed to be that extending from the mean high water line to a distance 50 ft into the channel. The excavated depth for the shoreline material was assumed to be 2 ft. The volumes associated with various reaches of the shoreline are shown in Figure 31. The material would be loaded in trucks and taken to a CDF for disposal. It was assumed that the volume of material excavated mechanically would not change.

In situ bottom materials in CDFs

152. The in situ bottom materials, as well as shoreline materials, within the boundaries of CDFs that would remain as permanent disposal sites were assumed to remain in place. For CAD option C, the in situ bottom material in the CDF was assumed to be dredged when material was redredged from the CDF to the CAD cell.

Dredging rate and sequence

153. The method of dredging assumed for the Upper Estuary is described in detail in Report 10. An 8-in. hydraulic dredge would be used, with an assumed average production rate of 800 cu yd per day. This production rate was used in calculation of the required time for dredging discrete horizontal areas and vertical thicknesses. Unlike the CDF alternative, which used lower production rates to allow tighter placement of volumes in the CDFs, the computations for the CAD alternative used the full 800 cu yd per day production for the entire time of filling. Also, times required for dredging a given area or vertical layer were separately considered for calculating volume change, rather than the total time for dredging required to fill the disposal site. These assumptions allowed for a greater margin of error in the sizing calculations.

154. In general, the progression of dredging was assumed to be from upstream to downstream. This allowed the more highly contaminated materials from the upper portion of the estuary to be removed first and placed in the CDFs.

155. The use of the grid cell system (Figure 10) established for sampling will be used for referencing and controlling dredging operations. All breaks between horizontal areas going to respective CDFs or to CAD cells were set to coincide with grid cell boundaries. This allowed calculations of volumes to be made on the basis of grid cells.

Material properties

156. For the CAD alternative, it is necessary to dredge both the surficial 2-ft thickness of contaminated material and underlying cleaner materials. Volume changes that occur due to dredging and placement in a CDF or CAD cell are a function of the settling properties, percent sand, and initial water content of the material dredged. The settling test results for the composite sample of the 2-ft contaminated layer and for the underlying clean materials (Report 7) were used for calculations involving those respective layers. Average values of percent sand and water content for a given horizontal area and vertical layer were used in the calculations. The breaks between vertical layers were assumed to coincide with those described in Appendix B and shown in Figure 11, i.e., corresponding to sediment depth ranges of 0 to 2 ft (contaminated material), 2 to 5 ft, 5 to 10 ft, and below 10 ft. The material properties for each respective grid cell are presented in Appendix B.

Side slopes

157. Preliminary analyses of excavated side slopes performed by the US Army Engineer Division, New England, indicate that a 1 vertical on 3 horizontal excavated slope will be stable. Sloughing of box cuts to conform to the stable side slopes during dredging is anticipated. The consideration of side slopes for the excavation of contaminated material is described in Report 10. For the deepest CAD cell excavation, the horizontal dimension of the slope will still be small in comparison to the areas being dredged. Therefore, for purposes of sizing, side slopes were assumed to have no influence on calculated volumes.

Hot spot

158. The hot spot is defined as that area with the highest PCB contamination, and generally corresponds to grid cells J7 and I11. For the CAD evaluation, the hot spot was assumed to be dredged along with materials in the adjacent cells. For all CAD options, the hot-spot material would be dredged and placed in a CDF where mixing with material of lesser contamination would occur.

Sizing results

159. Maps showing dredged areas, CDFs used, and CAD cell configurations for all three CAD options are presented as Figures 32-34. The sizing results are summarized in Tables 10-12. The tabulations indicate a dredging sequence

showing both dredged and disposed volumes, accounting for volume increases. Also shown are disposal locations, indicating which volumes fill a given CDF or CAD cell. Calculated storage capacities for CDFs and for CAD cells were balanced by trial and error with dredged material disposal volumes to within a few percent, considered to be within the accuracy of these calculations. An operations plan, to include more detailed configurations of CDFs and CAD cells and required sequencing of dredging, would be necessary for preparation of plans and specifications if a CAD option were selected for the cleanup. A description of the sizing process used for each CAD option is given in the following paragraphs.

160. CAD option A. The configuration of dredging and disposal areas for option A and the associated volumes are shown in Figure 32 and Table 10. Sites 1, 1A, and CDF 3 would be used for permanent disposal sites of the more contaminated material. The sequence of operations would be as follows:

a. Contaminated material along the shoreline, in Area A, and in Area B1 would be placed in CDF 3. The size of Area B1 was determined by trial to fill the remaining capacity of CDF 3 for contaminated material, leaving sufficient volume for a surface cover.

b. Area B1 would then be deepened to create CAD storage. The depth of subsequent excavation in B1 (indicated by grid cell in Figures 35 and 36) was determined by trial to provide sufficient clean material for the surface cover for CDF 3. This operation would close CDF 3.

c. Contaminated material in Areas B2 and B3 would be placed in CDFs 1 and 1A. The required volume matches that available in CDFs 1 and 1A for contaminated material.

d. Area B2 would then be deepened to create CAD storage and provide a surface cover for CDFs 1 and 1A. The depth of excavation in B2 (indicated by grid cell in Figures 35 and 36) was determined by trial to provide sufficient clean material for the surface cover for CDFs 1 and 1A. This operation would close CDFs 1 and 1A.

e. Contaminated material in Area C1 would be placed in CAD B1/B2. Area C1 was determined by trial to fill the available capacity for contaminated material in CAD B1/B2, leaving sufficient storage for the cap.

f. Area B3 would be deepened to create CAD storage and provide cap material for CAD B1/B2. The depth of excavation in B3 (indicated by grid cell in Figures 35 and 36) was determined by trial to provide sufficient capacity for the contaminated material from the remainder of the Upper Estuary. The required excavated volume exceeds the requirement for the cap for CAD B1/B2, so the remainder would be temporarily stored in CDFs below the bridge. This operation would close CAD B1/B2.

g. Contaminated material in Area C2 would be placed in CAD B3.

h. Material from the temporary CDFs below the bridge would be hydraulically redredged to provide the cap for CAD B3. The volume available exceeds the requirement, so the remainder would be used to partially restore the channel geometry in Areas C1 and C2.

161. CAD option B. The configuration of dredged areas and disposal areas for option B and the associated volumes are shown in Figure 33 and Table 11. Sites 1 and 1A would be used as a permanent disposal site for the more contaminated material. The sequence of operations would be as follows:

a. Contaminated material along the shoreline and in Area B would be placed in CDFs 1 and 1A. The size of Area B was determined by trial to fill the capacity of CDFs 1 and 1A for contaminated material, leaving sufficient volume for a surface cover.

b. Area B1 would then be deepened to create CAD storage and provide material for a surface cover for CDFs 1 and 1A. The depth of this excavation was 3 ft (indicated by grid cell in Figure 37), and the area of B1 was determined by trial to provide sufficient clean material for the surface cover for CDFs 1 and 1A. This operation would close CDFs 1 and 1A.

c. Area B would then be further deepened to create CAD storage. This deepening would be accomplished in stages. The initial depth of excavation in Area B2 and the depths of excavation for subsequent stages for all of Area B (indicated by grid cell in Figures 37-39) were determined by trial to provide sufficient CAD storage capacity for all remaining contaminated material. The excavated volume of clean material would be temporarily stored in CDFs below the bridge.

d. Contaminated material in Areas A and C would be placed in CAD B.

e. Material from the temporary CDFs below the bridge would be redredged to provide the cap for CAD B. This operation would close CAD B. The volume available exceeds the requirement, so the remainder would be used to partially restore the channel geometry in Area C.

162. CAD option C. The configuration of dredged areas and disposal areas for option C and the associated volumes are shown in Figure 34 and Table 12. No CDFs would be used as permanent disposal sites. The sequence of operations would be as follows:

a. Contaminated material along the shoreline and in Area B would be placed in CDF 1. The size of Area B is the largest available for a CAD site. No storage was provided for a surface cover for CDF 1 since it would be used only as a temporary site.

b. Area B would then be excavated to create CAD storage. This excavation would be accomplished in stages. The depths of excavation for all stages (indicated by grid cell in Figures 40-42) were determined by trial to provide sufficient CAD storage capacity for all remaining contaminated material. The excavated volume of clean material would be temporarily stored in CDFs below the bridge and at sites yet to be determined. The volume required exceeds the capacity of potential CDFs that have been identified to date.

c. Contaminated material in Areas A and C would be placed in CAD B.

d. Contaminated material in CDF 1, to include the in situ bottom sediments within the CDF, would be redredged and placed in CAD B.

e. Material from the temporary CDFs would be redredged to provide the cap for CAD B. The volume available exceeds the requirement, so the remainder would be placed in Area C. The volume available exceeds that required to restore Area C to its original configuration; therefore, the deep central channel would be filled to depths essentially equal to the surrounding tidal flats.

163. Option C requires a much larger volume of material to be dredged compared with other options, requires additional CDF storage capacity, and has a higher mass of contaminant release compared with other options. Therefore, it is not retained for detailed evaluation in Part VI.

Final Upper Estuary configuration

164. Since estimates of volume increases are overestimated, and the majority of the consolidation will occur within a few months following filling, the best assumption for the CAD cells is a return to predredging geometry. For channel areas outside the CAD cell, the bottom is lowered by 2 ft, but some areas are restored using excess clean material.

165. Final channel configurations within the Upper Estuary for each option are influenced by CDF construction and the volume occupied by material immediately after dredging. Summaries of the final configurations for CAD options A, B, and C by areas as indicated in Figures 32-34, respectively, are as follows:

a. Final configuration for CAD Option A:

Area A - 2 ft lower
Area B1/B2/B3 - original geometry
Area C1/C2 - 2 ft lower (excess for restoration is small)

CDFs 1, 1A, and 3 - filled to upland
No change below the bridge if site 12 is used

b. Final configuration for CAD Option B:

Area A - 2 ft lower
Area B1/B2 - original geometry
Area C - no change (excess essentially refills 2 ft)
CDFs 1 and 1A - filled to upland
CDFs 5 and/or 6 constructed below the bridge as preferred
No other change below the bridge if site 12 is used

c. Final configuration for CAD Option C:

Area A - 2 ft lower
Area B - original geometry
Area C (less central channel) - original geometry
Area C (central channel as indicated) - filled an average of 9 ft higher, essentially filling the channel level with the adjacent mudflat elevation
CDF 1 - original geometry
CDFs constructed below the bridge (both 5 and 6 required)
Sites 6 and 12 plus additional CDF capacity would be required

Monitoring Requirements

166. Monitoring would be required for the CAD alternative to ensure that contaminated material is adequately capped, contaminant releases are within acceptable levels, and long-term release of contaminants does not occur. Monitoring requirements for the dredging operations and for CDFs used for the CAD alternatives are identical to those for a CDF alternative. However, several monitoring tasks have been identified which pertain solely to the use of CAD cells. These are as follows:

a. Bathymetry surveys following CAD excavation, following placement of contaminated material, and following placement of the cap. These will confirm CAD cell sizing and volumetric capacity estimates during construction.

b. Water column sampling during CAD filling operations. This effort will determine the degree of contaminant release during filling.

c. Sediment cores taken in the excavated CAD cell(s) prior to filling with contaminated material and following filling and capping operations. This effort would confirm that contaminated material is placed and capped as called for in the design.

d. Periodic sediment cores taken through the cap and contaminated sediment. These cores will detect any migration of contaminants upward through the cap.

167. Similar monitoring efforts are planned for the pilot study. Results from the pilot study effort should be considered in developing a detailed monitoring plan for CAD if the CAD alternative is selected for the full-scale cleanup. Many of the additional monitoring tasks now planned for the pilot study would not be performed for the full-scale cleanup if pilot study results justify deletion of those tasks.

Controls for CAD Options

168. Additional controls to limit contaminant releases for the CAD options are associated with treatment of effluent from the CDFs necessary for CAD implementation. The CDF controls will be considered only for CAD option A since it provides the best opportunity to take advantage of the benefits of these controls. The same sequence of controls as for the CDF options is used. CAD option A1 includes chemical clarification, CAD option A2 adds filtration, and CAD option A3 adds carbon adsorption for treatment of effluent and surface runoff from the CDF. All three options include a surface cover.

PART VI: DETAILED ANALYSIS OF CDF AND CAD DESIGN OPTIONS

169. Evaluation of alternatives involves a determination of criteria for each alternative and a systematic comparison of alternatives in order to present relevant information for use by decisionmakers in selecting a remedy. Detailed descriptions of each of the design options evaluated by this report have been presented in Parts IV and V. The design options with combinations of additional controls are identified in Table 8. This part of the report presents a detailed evaluation of each of the design options in terms of selected USEPA criteria for evaluation of Superfund projects.

Evaluation Criteria

170. The USEPA directive "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (USEPA 1988) prescribes nine criteria for assessment of remedial action alternatives for Superfund sites. These criteria were selected by USEPA to meet the statutory requirements of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), as well as additional technical and policy considerations important to evaluating and selecting remedial alternatives. These criteria are listed and briefly described below:

- a. Short-term effectiveness. This criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation period until response objectives have been met.
- b. Long-term effectiveness and permanence. This criterion evaluates the long-term effectiveness of alternatives in protecting human health and the environment after response objectives have been met.
- c. Reduction of toxicity, mobility, and volume. This criterion evaluates the anticipated performance of the specific treatment technologies.
- d. Implementability. This criterion evaluates the technical and administrative feasibility of alternatives and the availability of required resources.
- e. Cost. This criterion evaluates the capital and O&M costs of each alternative.
- f. Compliance with applicable or appropriate and relevant requirements (ARARs). This criterion describes how the

alternative complies with ARARs, or if a waiver is required and how it would be justified.

g. Overall protection. This criterion describes how the alternative, as a whole, protects and maintains protection of human health and the environment.

h. State acceptance. This assessment reflects the state's apparent preferences or concerns regarding the alternative.

i. Community acceptance. This assessment reflects the community's apparent preferences or concerns regarding the alternative.

171. The scope of this EFS does not include an evaluation of all of the USEPA criteria. Criteria dealing with specific environmental impacts, risk evaluation, compliance with ARARs, state acceptance, and community acceptance will not be addressed in this report but will be addressed by the overall site Feasibility Study being prepared by E. C. Jordan Company. Therefore, the evaluation presented below will consider criteria a through e. Short- and long-term effectiveness will focus on contaminant release without discussing specific impacts on human health and the environment.

Detailed Evaluation

Short-term effectiveness

172. Short-term effectiveness addresses protection of the community and workers during remedial actions, contaminant releases that may cause environmental impacts during implementation, and the time required for implementation of the alternative. Shortterm is considered the time required to complete the dredging and disposal operations, including placement of the surface cover.

173. Option CDF A1. Dredging the Upper Estuary with the small hydraulic dredges recommended by this study will have minor impacts on the community. The dredging operation will be sufficiently removed from the public to minimize health and safety concerns associated with the sediment removal operation. Dredge operators will have to take appropriate protective measures to prevent direct contact with the contaminated sediment, particularly during maintenance of dredging equipment. The CDFs used for this option will be located in proximity to the public and will require restrictions to prevent access by the public to the CDF sites. Air transport of volatilized PCBs from the CDFs to human receptors is a concern, but reducing direct exposure of the contaminated sediment to air will minimize the potential for PCB

volatilization. Air monitoring during disposal operations should be included as a component of a detailed health and safety plan for the action.

174. Estimated contaminant releases for PCB and copper are presented in Appendix D (Tables D5 and D7). These releases will affect water quality and, potentially, aquatic organisms in the estuary. More than half of the estimated contaminant release is associated with resuspension by the dredge. Silt curtains or screens will be used around the dredge to reduce transport out of the Upper Estuary. Estimated time for implementation of the alternative is 5 years (see Figure C1, Appendix C). Time for recovery of the Upper Estuary from existing contamination is being evaluated by others.

175. Option CDF A2. Effects of this option on the community and workers are the same as for option CDF A1. One additional concern for workers involves the filtration unit for CDF effluent. Personal protective measures will be required when operating and maintaining this equipment, and the fouled filter media will have to be handled as a hazardous waste. Contaminant release estimates, presented in Tables D5 and D7, show that the contaminant load is slightly reduced from CDF A1 as a result of filtration of CDF effluent. Time for implementation is 5 years.

176. Option CDF A3. Short-term effectiveness for this option is essentially the same as for CDF A2 with the additional PCB removal afforded by the additional treatment unit. Worker protection while operating and maintaining the treatment system is a consideration but not an obstacle. Disposal of the spent carbon from a carbon adsorption system will be required to derive benefits from the PCB removal process. Time for implementation is 5 years.

177. Option CDF B1. Short-term effectiveness is the same as for CDF A1 except that additional contaminants are released because of the larger dredging volume required for the dredging sequence for Option B. Time for implementation is 6 years.

178. Option CDF B2. The same considerations for CDF A2 and CDF B1 apply to the short-term effectiveness for this option. Time for implementation is 6 years.

179. Option CDF B3. The same considerations for CDF A3 and CDF B1 apply to the short-term effectiveness for this option. Time for implementation is 6 years.

180. Option CDF C1. Short-term effectiveness of this option is improved by the reduced contaminant release attributed to liners installed in

CDFs 6 and 12 for leachate control. On the other hand, protection of the community and the surface water pathway becomes more of a concern because the most contaminated material is transported downstream below the Coggeshall Street Bridge and because this option requires removal of more material than CDF options A and B. Pipeline leaks or ruptures during this operation would have a greater chance for impact on downstream water uses. This option requires 5.25 years to implement (Figure C3).

181. Option CDF D1. The provision for liners at all CDF sites provides the most control and protection of the community and the environment from contaminant releases at the CDF. However, the larger dredge volumes required to be removed in order to construct the lined CDFs (see Tables 3-6) offset the liner benefits because of increased total losses at the dredgehead. This option retains the most contaminated sediment in CDFs above the bridge but requires an extremely long time (11.5 years) to implement.

182. Option CAD A1. Short-term effectiveness for option CAD A1 is less than for any of the CDF options because of the contaminant releases associated with filling of the CAD cells with contaminated material. Impacts of this option on the community are associated with contaminant releases to the water column during dredging and CAD filling. However, all CDFs and CAD cells for contaminated material are located above the bridge, and disposal operations are confined to a smaller area than for the CDF options. Time for implementation of this option is 7.25 years.

183. Option CAD A2. Short-term effectiveness for this option is the same as option CAD A1 with only a slight reduction in contaminant release by filtration of CDF effluent.

184. Option CAD A3. Short-term effectiveness for this option is the same as option CAD A1 with only a slight reduction in contaminant release by filtration and PCB removal for CDF effluent.

185. Option CAD B. Short-term effectiveness for option CAD B is degraded because of the relatively high contaminant release amounts associated with disposal of a substantial fraction of the contaminated material in CAD cells. The time required to implement the alternative is 9.5 years.

Long-term effectiveness and permanence

186. The focus of this evaluation criterion is the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals or untreated waste. Analysis factors include the

magnitude of residual risks, adequacy of controls, and reliability of controls (USEPA 1988). The magnitude of remaining risks and impacts of contaminated sediment remaining in the Upper Estuary will not be included in this evaluation. Long term is defined to mean effectiveness of the remedial action after the CDFs or CAD cells are filled and capped.

187. General observations - CDF options. The functions of CDFs as evaluated for this EFS are to isolate the contaminated sediment from the environment and to provide for long-term storage of the contaminated sediment. Long-term reliability of the CDFs to contain the contaminants depends on the ability to maintain an effective cap on the surface of the CDF and prevent infiltration of precipitation or breach of the cap by human activities, wildlife, or vegetation. Management of the site will include maintenance of the cap and operation of additional controls for some design options.

188. All sites will require long-term monitoring to detect movement of contaminants beyond the boundaries of the site. The primary pathway for movement of contaminants from the sites will be leachate losses to ground water. The analysis of water movement from CDFs with an effective surface cover (Appendix D) shows that the contaminant loss by this mechanism will produce relatively small quantities of contaminant release compared with current releases at the Coggeshall Street Bridge (see Report 2). If monitoring wells detect unacceptable losses of contaminants from the CDFs, additional controls could be implemented. Movement of leachate from the sites could be controlled by barriers to ground-water movement such as slurry walls or by in situ stabilization of the dredged material to bind free water in the dredged material into a solidified mass. Removal of the dredged material for storage at a more secure facility or for treatment to remove or destroy contaminants could also be implemented. Excavation of the partially dewatered dredged material could be accomplished mechanically without the addition of water, in much the same way that other FS alternatives will handle dredged material for further processing. However, the volume of dredged material to be handled would be increased because of the additional volume of potentially contaminated capping and dike material.

189. Evaluation of long-term effectiveness for the CDF design options is not influenced by the type of effluent treatment during dredging and disposal. Therefore, CDF design options A1, A2, A3 and B1, B2, B3 need not be discussed separately.

190. Options CDF A and CDF B. These options do not include any leachate controls except for surface covers. Small quantities of leachate from the CDFs cannot be controlled. The magnitude of the leachate losses cannot be predicted precisely, but the release rates presented in Appendix D were selected to represent the worst case, based on available information and leachate testing. The affinity of the contaminants for particulate material, as evidenced by their retention in Upper Estuary sediments, suggests that containment of the particulate matter in the CDFs in an anoxic environment will also contribute to retention of the contaminants in the CDF.

191. Ground-water monitoring for the nearshore CDFs will provide qualitative and quantitative information on contaminants moving through the dike and bottoms of the CDFs. However, ground-water flow data, which are necessary to estimate contaminant flux, will be more difficult to collect, and this deficiency will present difficult decisions on the long-term effectiveness of the remedial action. Consolidation of the dredged material and underlying foundations, particularly for in-water sites, will continue in the long term and will require careful monitoring and maintenance. Differential settling within the CDF could impact on performance of the hydraulic barrier portion of the surface cover and require replacement at some future date.

192. Option CDF C. This option improves on CDF A and CDF B by placing the most contaminated dredged material in lined CDFs at CDF sites 6 and 12. The lined sites provide better control and monitoring of leachate. Consolidation of the dredged material will be accomplished faster by the leachate collection feature of the lined CDFs. Hence, a more reliable cover can also be installed at an earlier date. Long-term reliability of liners is a concern discussed further in Report 8. Failures of synthetic membrane liners are not uncommon (Bass, Lyman, and Tratnyek 1985), and liners should not be considered as completely impermeable.

193. Option CDF D. This option includes liners at all CDF locations and represents the best degree of long-term containment of contaminants placed in the CDFs. Extensive long-term maintenance of the lined CDFs for nearshore locations will be required because of the difficulty in preparing a suitable foundation for installation of the liner system. The reliability of these liner systems is judged to be low.

194. CAD options. Long-term effectiveness for each design option (A and B) for the CAD alternative is essentially the same and will not be

discussed separately. The CDFs required for the CAD design options have the same long-term effectiveness as the CDF options A and B, as discussed above. This section will focus on the CAD cells.

195. Monitoring of capped sites for other projects dealing with contaminated dredged material has not indicated any significant potential for long-term migration of contaminants upward through the cap. Uncertainties for the CAD cells evaluated for New Bedford are associated with ground-water flow upward through the cap, erosion of the cap by extreme storm events, or breaching of the cap by deep-burrowing organisms currently not active in this area. Monitoring of the physical integrity of the cap and contaminant movement through the cap will provide warning of the need for remedial action. Additional capping material (thickness constrained by mean low water elevation) can be added if the need arises. If the effectiveness of the cap is maintained, the reliability of the CAD alternative in containing contaminants is expected to be good.

196. Comparison of effectiveness for design options. Table 13 summarizes the assessment of short-term and long-term effectiveness. Options A3, B3, C, and D were given a "high" rating for short-term effectiveness, and option D was a given a high rating for long-term effectiveness.

Reduction of toxicity, mobility, and volume

197. This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances. These technologies should destroy toxic contaminants, reduce the total mass of toxic contaminants, irreversibly reduce contaminant mobility, or reduce the total volume of contaminated media (USEPA 1988).

198. The CDF and CAD alternatives in general do not achieve the objectives stated for this criterion. Contaminants in the dredged material are not treated, destroyed, or reduced in toxicity or volume. The volume of contaminated material may actually increase because of water entrained by dredging and partial mixing of clean capping materials with contaminated sediment. Reduction in volume for contaminated soils is difficult for any technology.

199. The CDF and CAD alternatives remove an estimated 99+ percent of the PCBs in the top 2 ft of sediment in the Upper Estuary and isolate the contaminants from the environment by capping and/or containment in diked disposal areas. This reduces the flux of contaminants leaving the Upper Estuary and

reduces toxicity within the estuary and harbor. On the basis of this improvement, all CDF and CAD options were assigned a moderate rating for this criterion.

Implementability

200. The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. Technical feasibility includes difficulties and unknowns associated with construction and operation, reliability, ease of undertaking additional remedial action, and monitoring considerations. Administrative feasibility includes activities needed to coordinate with other offices and agencies (USEPA 1988). Design options will be given one of the following implementability ratings:

a. Easy or possible to implement.

b. Moderate difficulties in implementation.

c. Substantial difficulties in implementation.

201. Option CDF A1. The primary difficulties in construction of CDFs for this option are associated with construction of the in-water dikes for the nearshore CDFs. The soft foundations for these dikes will require staged construction to allow for consolidation of the underlying sediment. Uncertainties associated with this process have caused construction delays for the dikes for the Pilot Study CDF. A second construction problem is the requirement for timely placement of a cap on the contaminated dredged material to avoid volatilization, surface runoff, and infiltration losses. There is some uncertainty in the length of time for consolidation of the dredged material to a moisture content that will allow working on the site with the equipment needed to place a low-permeability cover.

202. The reliability of CDFs to contain solids and provide effective sedimentation and clarification has been demonstrated. Future remedial actions could be undertaken by removing material from the CDFs for further processing or treatment. Monitoring of the CDFs for ground-water contamination is recommended. As stated in the above under discussion of long-term effectiveness, quantification of leachate and ground-water flow rates is necessary to calculate the rate of contaminant loss by this pathway, but this is a challenging technique to implement. Administrative feasibility may be hampered by the problems in obtaining disposal sites and the reluctance of regulatory agencies to accept unlined disposal facilities for a hazardous

waste. Materials and services for implementation of this option are available, with the possible exception of geotextile material used as a component of the in-water dikes, which is available from a limited number of sources. The overall implementability rating of this option is high.

203. Option CDF A2. Implementability for this option is the same as for CDF A1 with additional consideration of the filtration step for the CDF effluent. Filtration is a readily available, reliable, proven technology for suspended solids removal. The implementability rating for this option is high.

204. Option CDF A3. Implementability for this option is the same as for CDF A2 with the additional consideration of the PCB removal step. Carbon adsorption is easy to implement and has been proven reliable for PCB removal. There is some uncertainty as to the ability of the process to remove contaminants associated with fine particulate or colloidal matter that may pass through the carbon column. The UV/peroxide treatment has not been demonstrated for PCBs but has been demonstrated to be effective for similar organic compounds. Both carbon adsorption and UV/peroxide will be field tested during the Pilot Study. Implementability of this option is high.

205. Options CDF B1/B2/B3. Implementability ratings for these options are the same as for CDF A1, A2, and A3. Removal of the contaminated sediment from CDF site 1B prior to building the in-water dike should reduce difficulties in construction for this site compared with CDF A.

206. Options CDF C. Implementability for this option requires consideration of the same factors as CDF A1 for the nearshore CDF sites, plus consideration of construction of the liner installation at CDF sites 6 and 12. Installation of liners at upland CDFs should not present unusual difficulties in construction but will require careful construction techniques and intensive inspection during installation. The lined sites offer improved monitoring capability for leachate from the CDFs containing the most highly contaminated dredged material. Implementability rating for this option is high.

207. Option CDF D. This option requires the installation of lined sites at the nearshore CDF sites. The construction sequence outlined for this component of the design option is full of uncertainty. Hydraulic placement of the fill to raise the bottom elevation above high-water elevation will require careful selection of material and control during construction. The volume of material and the length of time for consolidation and desiccation of this material prior to installation of the liner system are estimates with the

potential for high variability. Once the liner is in place, placement of the contaminated dredged material and surface cap on top of the liner may cause uneven settling, disrupt the leachate collection system, and puncture or tear the liner. Reliability of this system is poor because it is not likely to meet the objective of containment or collection and treatment of leachate. Administrative feasibility of this option is improved because it attempts to meet the ARAR for lining of hazardous waste sites. Materials and facilities for this option are available. Implementability of this option is rated low.

208. Option CAD A. An analysis of the sequence of construction for implementing the CAD options is provided in Part V. The CAD cells have been overdesigned in order to avoid schedule delays during construction. Implementability of the CDFs associated with this option is the same as described for option CDF A1. The CAD cells can be reliably excavated using hydraulic dredging equipment. There will be some sloughing of side walls, but this is not expected to impact the CAD volume significantly. Uncertainty in the ability to place the contaminated material in the CAD without large losses of contaminants during filling and prior to placement of the cap is an issue. Time required for consolidation of the contaminated layer and the capping material and the degree of mixing of cap material with the contaminated dredged material are concerns. The reliability of this type of construction in a shallow estuary has not been demonstrated. Filling and capping the CAD cells with hydraulic dredges has been implemented in a project at Rotterdam Harbor, the Netherlands (d'Angremond, de Jong, and de Waard 1986). A CAD cell for New Bedford sediment is scheduled to be tested during the Pilot Study. Water quality monitoring during the CAD filling operation can adequately characterize contaminant losses from the operation. Administrative feasibility could be improved by the reduced requirement for land to construct CDFs for contaminated material. Availability of services and materials for this option is not an issue. The overall implementability rating for the option is moderate.

209. Option CAD B. Implementability for this option is basically the same as for CAD A. The requirement for fewer CDFs for contaminated material offers a slight advantage to CAD A.

Cost

210. The cost evaluation criterion includes capital costs for construction, equipment, land, buildings and services, relocation expenses, disposal

costs, engineering expenses, legal fees and license or permit costs, startup and shakedown costs, and contingency allowances. The cost criterion also considers annual postconstruction, or O&M, costs necessary to ensure the continued effectiveness of the remedial action (USEPA 1988).

211. Appendix C presents the construction and O&M costs for CDF and CAD design options developed by this study. A summary of these costs is presented in Table 14. Not included in the costs are estimates for the land costs necessary for construction of the CDFs, which will constitute a major additional cost. However, this additional cost will not vary significantly for the different CDF disposal options evaluated, since all require purchasing land for CDFs. The CAD alternatives should save on land costs since the upland CDFs used for this option will be temporary storage sites for clean dredged material.

Summary

212. Table 15 summarizes the results of the detailed evaluation of design options in terms of short-term effectiveness, long-term effectiveness, implementability, and costs. As stated above, all design options reviewed by this study would rate moderate for the reduction of toxicity, mobility, or volume criterion.

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Table 1

Heavy Metals Concentrations, Acushnet River Estuary Sediment

Contaminant	Mean Concentration ppm	Standard Error ppm	No. Samples
Arsenic	4.5	0.53	31
Cadmium	18	3.9	31
Chromium	350	68	31
Copper	820	130	31
Lead	390	64	31
Mercury	0.75	0.084	31
Nickel	76	16	31
Zinc	1,500	220	31

Source: US Army Engineer District, New England (1986 data).

Table 2

Confined Disposal Facility Capacities

Site	Capacity cu yd	Surface Area sq ft
1	270,067	900,000
1A	28,318	130,000
1B	89,894	210,000
3	134,654	500,000
5	92,855	250,000
6	91,240	400,000
12	325,595	800,000
Total	1,032,623	3,190,000

Table 3

CDF Design Option A, Design for Solids Storage

CDF No.	Range Dredged	Depth of Cut ft	Total Area acres	Average Sand Fraction %	Average Water Content %	Total In Situ Volume cu yd	In Situ Sand Volume cu yd	In Situ Fine-Grained Volume cu yd	Dredging Rate cu yd/day	Dredging Time days	In Situ Voids Ratio	CDF Solids Concentration g/ℓ	CDF Voids Ratio	CDF Volume Fine-Grained cu yd	CDF Total Volume cu yd	CDF Available Volume cu yd	Bulking Factor
1B	C2...J12	0-1	21	48	120	34,398	16,360	18,038	600	57	3.0	315	6.9	35,745	52,105	70,000	1.51
	J7	1-3															
	I11	1-3															
	Mechanical dredge					16,500									16,500		
1	K2...N12	0-1	116	43	116	186,759	80,105	106,654	700	267	2.9	370	5.8	184,934	265,039	270,000	1.42
	C13...N31	0-1															
	Mechanical dredge					4,400									4,400		
3	C2...N17	1-2	59	43	124	95,116	41,187	53,929	500	190	3.1	357	6.0	92,151	133,338	134,000	1.40
12	C32...N33	0-1	91	47	98	147,153	69,743	77,410	800	184	2.4	356	6.0	157,691	227,433	325,000	1.55
	C18...N33	1-2															
	Total					484,326									698,815	799,000	

Table 4

CDF Design Option B, Design for Solids Storage

CDF No.	Range Dredged	Depth of Cut ft	Total Area acres	Average Sand Fraction %	Average Water Content %	Total In Situ Volume cu yd	In Situ Sand Volume cu yd	*In Situ* Fine-Grained Volume cu yd	Dredging Rate cu yd/day	Dredging Time days	In Situ Voids Ratio	*CDF* Solids Concentration g/ℓ	CDF Voids Ratio	*CDF* Volume Fine-Grained cu yd	CDF Total Volume cu yd	CDF Available Volume cu yd	Bulking Factor
1	C2...N24	0-1	103	43	124	165,463	70,494	94,969	800	207	3.1	360	5.9	160,921	231,415	270,000	1.40
	Mechanical dredge					30,000									30,000		
3	C2...N15	1-2	60	42	123	96,782	40,513	56,270	400	242	3.1	366	5.8	94,056	134,569	134,000	1.39
	J7,I11	2-3															
IB	C16...N20	1-2	24	40	130	38,704	15,389	23,314	800	48	3.3	309	7.1	44,306	59,695	70,000	1.54
12	C25...N33	0-1	114	48	91	183,310	87,670	95,640	800	229	2.3	364	5.9	200,425	288,095	325,000	1.57
	C21...N33	1-2															
	Total					514,259									743,774	799,000	

Table 5

CDF Design Option C, Design for Solids Storage

CDF No.	Range Dredged	Depth of Cut ft	Total Area acres	Average Sand Fraction %	Average Water Content %	Total In Situ Volume cu yd	In Situ Sand Volume cu yd	In Situ Fine-Grained Volume cu yd	Dredging Rate cu yd/day	Dredging Time days	In Situ Voids Ratio	CDF Solids Concentration g/ℓ	CDF Voids Ratio	CDF Volume Fine-Grained cu yd	CDF Total Volume cu yd	CDF Available Volume cu yd	Bulking Factor
12	C2...K28	0-1	144	42	120	232,870	97,437	135,433	800	291	3.0	374	5.7	226,495	323,932	325,000	1.39
6	C5...J13	1-2	44	31	132	71,713	22,048	49,665	266	270	3.3	371	5.7	77,749	99,797	100,000	1.39
	C14...H21	1-2															
	J7,I11	2-3															
	M6...N7	1-2															
1	C2...N4	1-2	100	52	97	161,273	84,004	77,269	600	269	2.4	370	5.7	152,313	236,317	270,000	1.47
	K5...L7	1-2															
	K8...N13	1-2															
	I14...N21	1-2															
	C22...N24	1-2															
	C29...N33	0-1															
	L28...N28	0-1															
	Mechanical dredge					30,500									30,500		
3	H25...N27	1-2	48	48	85	77,616	37,088	40,528	300	259	2.1	369	5.8	87,573	124,661	134,000	1.61
	H28...J28	1-2															
	G29...J33	1-2															
	Total					573,972									815,206	829,000	

Table 6

CDF Design Option D, Design for Solids Storage

CDF No.	Range Dredged	Depth of Cut ft	Total Area acres	Average Sand Fraction %	Average Water Content %	Total In Situ Volume cu yd	In Situ Sand Volume cu yd	In Situ Fine-Grained Volume cu yd	Dredging Rate cu yd/day	Dredging Time days	In Situ Voids Ratio	CDF Solids Concentration g/l	CDF Voids Ratio	CDF Volume Fine-Grained cu yd	CDF Total Volume cu yd	CDF Available Volume cu yd	Bulking Factor
12	C2...N27	0-1	144	42	120	231,690	96,943	134,747	800	290	3.0	373	5.7	225,467	322,410	325,000	1.39
	C28...K28	0-1															
6	C5...J13	1-2	43	37	127	69,444	25,694	43,750	258	269	3.2	370	5.7	70,672	96,367	100,000	1.39
	C25...G28	1-2															
	J7,I11	2-3															
1	C2...N4	1-2	95	48	100	152,778	73,398	79,379	600	255	2.5	368	5.8	154,368	227,766	270,000	1.49
	K5...N13	1-2															
	C14...N21	1-2															
	K29...N33	0-1															
	L28,M28	0-1															
	K27...N33	1-2															
	Mechanical dredge					42,000									42,000		
3	C22...N24	1-2	54	44	100	86,921	38,593	48,328	322	270	2.5	371	5.7	92,908	131,501	134,000	1.51
	H25...N26	1-2															
	H27...J28	1-2															
	C29...J32	0-1															
1B	C33...J33	0-1	26	48	77	41,944	19,959	21,986	156	269	1.9	370	5.7	50,851	70,810	70,000	1.69
	C29...J32	1-2															
	G33,H33	1-2															
	Mechanical dredge					8,000									8,000		
	Total					632,777									898,854	899,000	

Table 7

Control Technologies for CDF Options

Contaminant Pathway	Control
Effluent (hydraulic filling)	Settling Chemical clarification Filtration Carbon adsorption Oxidation (UV/hydrogen peroxide)
Runoff	Settling Chemical clarification Filtration Carbon adsorption Oxidation (UV/hydrogen peroxide) Surface cover
Leachate	Liner with leachate collection Filtration Carbon adsorption Oxidation (UV/hydrogen peroxide) Surface cover
Volatilization	Ponding Surface cover
Plant/animal uptake	Surface cover

Table 8

CDF Options with Additional Control Technologies

Option	Option/Control Combinations
CDF A1	CDF option A + chemical clarification + surface cover
CDF A2	CDF option A + chemical clarification + filtration + surface cover
CDF A3	CDF option A + chemical clarification + filtration + carbon adsorption + surface cover
CDF B1	CDF option B + chemical clarification + surface cover
CDF B2	CDF option B + chemical clarification + filtration + surface cover
CDF B3	CDF option B + chemical clarification + filtration + carbon adsorption + surface cover
CDF C	CDF option C + chemical clarification + filtration + liner/leachate collection + carbon adsorption + surface cover
CDF D	CDF option D + chemical clarification + filtration + liner/leachate collection + carbon adsorption + surface cover
CAD A1	CAD option A + CDF effluent treatment (chemical clarification) + CDF surface cover
CAD A2	CAD option A + CDF effluent treatment (chemical clarification + filtration) + CDF surface cover
CAD A3	CAD option A + CDF effluent treatment (chemical clarification + filtration + carbon adsorption) + CDF surface cover
CAD B	CAD option B + CDF effluent treatment (chemical clarification) + CDF surface cover

Table 9

Characteristics of Confined Disposal Facilities

No.	Location	Capacity cu yd (1)	Surface Area sq ft (2)	Capacity 4-ft Cap cu yd (3)	2-ft Pond cu yd (4)	Maximum Containment Storage cu yd (Col 1 + 4 - 3)	Maximum Total Storage cu yd (Col 1 + 4)
1	West Cove	270,067	900,000	133,333	66,667	203,400	336,734
1A	West Cove	28,318	130,000	19,259	9,630	18,688	37,948
3	East Cove	134,654	500,000	74,074	37,037	97,617	171,691
6	Marsh Island	91,240	400,000	59,259	29,630	61,610	120,870
12	Railroad yard	325,595	800,000	118,519	59,259	266,336	384,854

Table 10

Dredging Sequence and Volumes for CAD Option A

Dredged Area	Dredged Layer	Dredged Volume cu yd	Dredging Time days	Disposal Site	Disposal Volume cu yd
Shoreline	--	26,100	32	CDF 3	26,100
A	0-2 ft	29,583	37	CDF 3	46,610
B1	0-2 ft	15,741	20	CDF 3	27,762
B1	2-5 ft	20,833	26	CDF 3	26,209
B1	5-10 ft	39,120	49	CDF 3	44,980
B2,B3	0-2 ft	156,852	196	CDF 1/1A	221,958
B2	2-5 ft	72,917	91	CDF 1/1A	94,785
B2	5-10 ft	42,130	53	CDF 1/1A	58,357
C1	0-2 ft	98,981	124	CAD B1/B2	142,761
B3	2-5 ft	116,667	146	CAD B1/B2	146,126
B3	5-10 ft	175,926	220	Temporary CDF	237,976
C2	0-2 ft	170,648	213	CAD B3	272,423
Temporary CDF	--	155,556	194	CAD B3	155,556
Temporary CDF	--	82,420	103	Restore C	82,420
Total		1,203,474	1,504		1,584,023

Table 11

Dredging Sequence and Volumes for CAD Option B

Dredged Area	Dredged Layer	Dredged Volume cu yd	Dredging Time days	Disposal Site	Disposal Volume cu yd
Shoreline	--	34,500	43	CDF 1/1A	34,500
B	0-2 ft	124,583	156	CDF 1/1A	174,834
B1	2-5 ft	127,778	160	CDF 1/1A	155,201
B2	2-5 ft	20,833	26	Temp CDF	31,450
B	5-10 ft	247,685	310	Temp CDF	311,813
B	Below 10 ft	214,120	268	Temp CDF	214,120
C	0-2 ft	364,306	455	CAD B	529,621
A	0-2 ft	29,583	37	CAD B	46,610
Temporary CDF	--	198,148	248	CAD B	198,148
Temporary CDF	- -	359,236	449	Restore C	359,236
Total		1,720,772	2,152		2,055,533

Table 12

Dredging Sequence and Volumes for CAD Option C

Dredged Area	Dredged Layer	Dredged Volume cu yd	Dredging Time days	Disposal Site	Disposal Volume cu yd
Shoreline	--	50,400	63	CDF 1	50,400
B	0-2 ft	172,593	216	CDF 1	243,135
B	2-5 ft	203,472	254	Temp CDF	135,043
B	5-10 ft	339,120	424	Temp CDF	418,797
B	Below 10 ft	406,944	509	Temp CDF	406,944
C	0-2 ft	316,296	395	CAD B	464,003
A	0-2 ft	29,583	37	CAD B	46,610
CDF 1	--	109,242	137	CAD B	170,491
CDF 1	--	243,134	304	CAD B	242,134
Temp CDF	--	271,296	339	CAD B	271,296
Temp CDF	--	789,488	986	Restore C	789,488
Total		2,931,568	3,664		3,238,341

Table 13

Effectiveness Evaluation Summary

Design Option	Short-Term PCB Loss kg	Short-Term Copper Loss kg	Short-Term Effectiveness Rating	Long-Term PCB Loss kg	Long-Term Cu Loss kg	Long-Term Effectiveness Rating*
CDF A1	933	693	Moderate	190	6	Low
CDF A2	901	581	Moderate	190	6	Low
CDF A3	657	570	High	190	6	Low
CDF B1	991	736	Moderate	199	6	Low
CDF B2	957	617	Moderate	199	6	Low
CDF B3	698	605	High	199	6	Low
CDF C	778	676	High	105	6	Moderate
CDF D	859	747	High	2	6	High
CAD A1	1,424	1,543	Low	159	5	Moderate
CAD A2	1,410	1,490	Low	159	5	Moderate
CAD A3	1,294	1,485	Low	159	5	Moderate
CAD B	1,746	2,005	Low	160	4	Moderate

* Short- and long-term contaminant releases (from Appendix D) were considered in assigning the long-term effectiveness rating.

Table 14

Cost Summary

Design Option	Capital Cost ($000)	Present Worth of O&M Cost* ($000)	Total Present Worth Cost ($000)
CDF A1	27,779	2,524	30,303
CDF A2	30,336	3,022	33,358
CDF A3	33,211	4,184	37,395
CDF B1	28,150	2,524	30,674
CDF B2	30,706	3,022	33,728
CDF B3	33,582	4,184	37,766
CDF C	36,294	5,049	41,343
CDF D	56,504	8,477	64,981
CAD A1	33,296	2,809	36,105
CAD A2	35,852	3,149	39,001
CAD A3	38,728	3,942	42,670
CAD B	34,846	2,528	37,374

* Present worth calculated using 5-percent discount rate and 30-year project.

Table 15

Evaluation of Alternatives Summary

Design Option	Short-Term Effectiveness Rating	Long-Term Effectiveness Rating	Mobility Reduction Rating	Implementability Rating	Present Worth Cost ($000)
CDF A1	Moderate	Low	Moderate	High	30,303
CDF A2	Moderate	Low	Moderate	High	33,358
CDF A3	High	Low	Moderate	High	37,395
CDF B1	Moderate	Low	Moderate	High	30,674
CDF B2	Moderate	Low	Moderate	High	33,728
CDF B3	High	Low	Moderate	High	37,766
CDF C	High	Moderate	Moderate	High	41,343
CDF D	High	High	Moderate	Low	64,981
CAD A1	Low	Moderate	Moderate	Moderate	36,105
CAD A2	Low	Moderate	Moderate	Moderate	39,001
CAD A3	Low	Moderate	Moderate	Moderate	42,670
CAD B	Low	Moderate	Moderate	Moderate	37,374

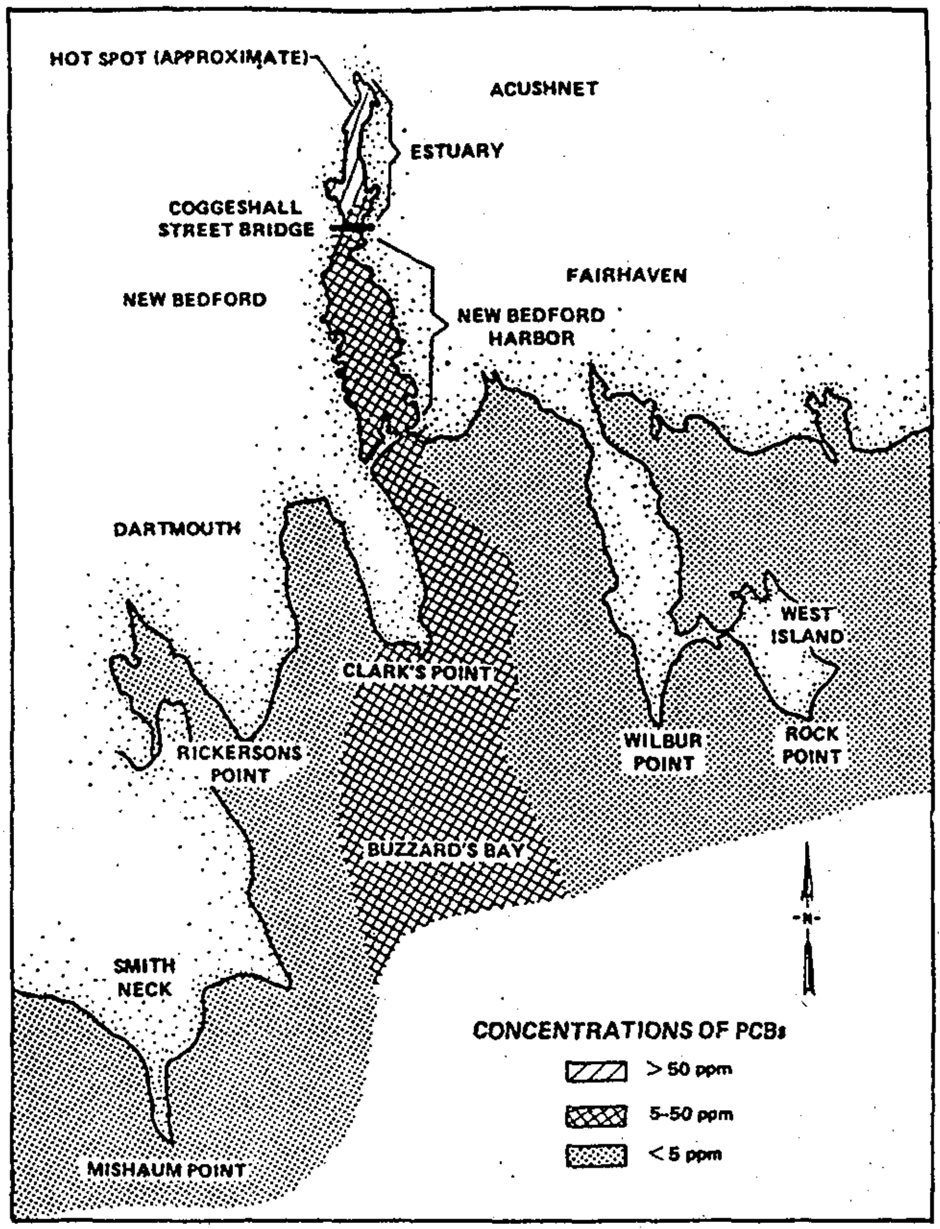


Figure 1. New Bedford Superfund site, New Bedford, MA (USEPA 1987)

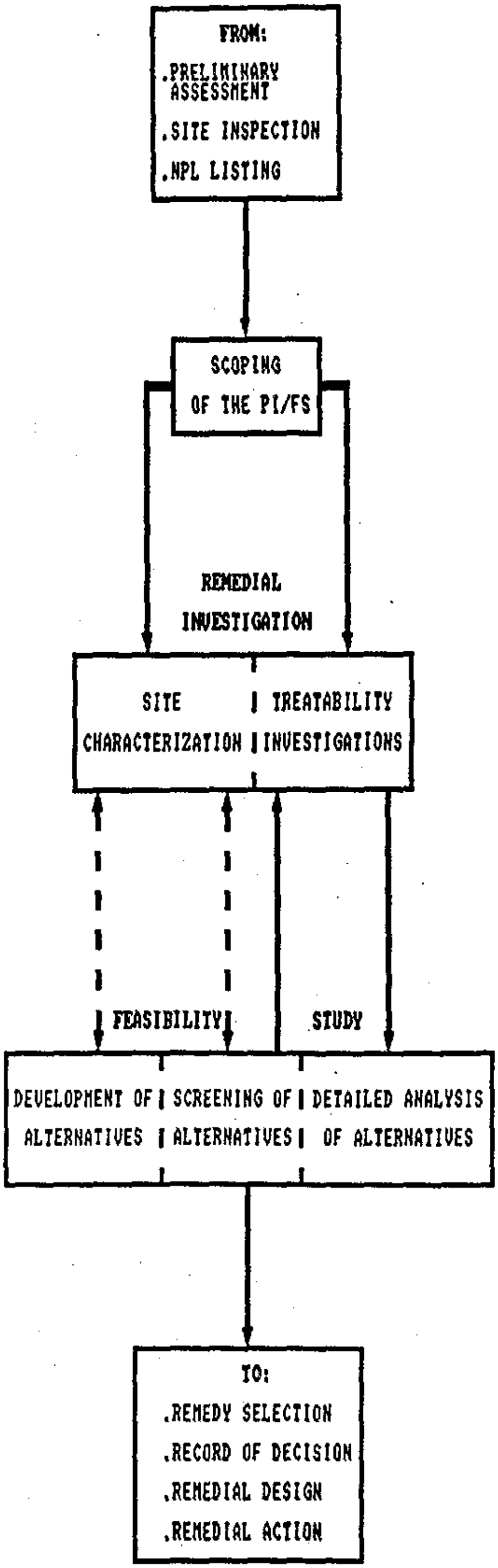


Figure 2. Phased remedial investigation/feasibility study process

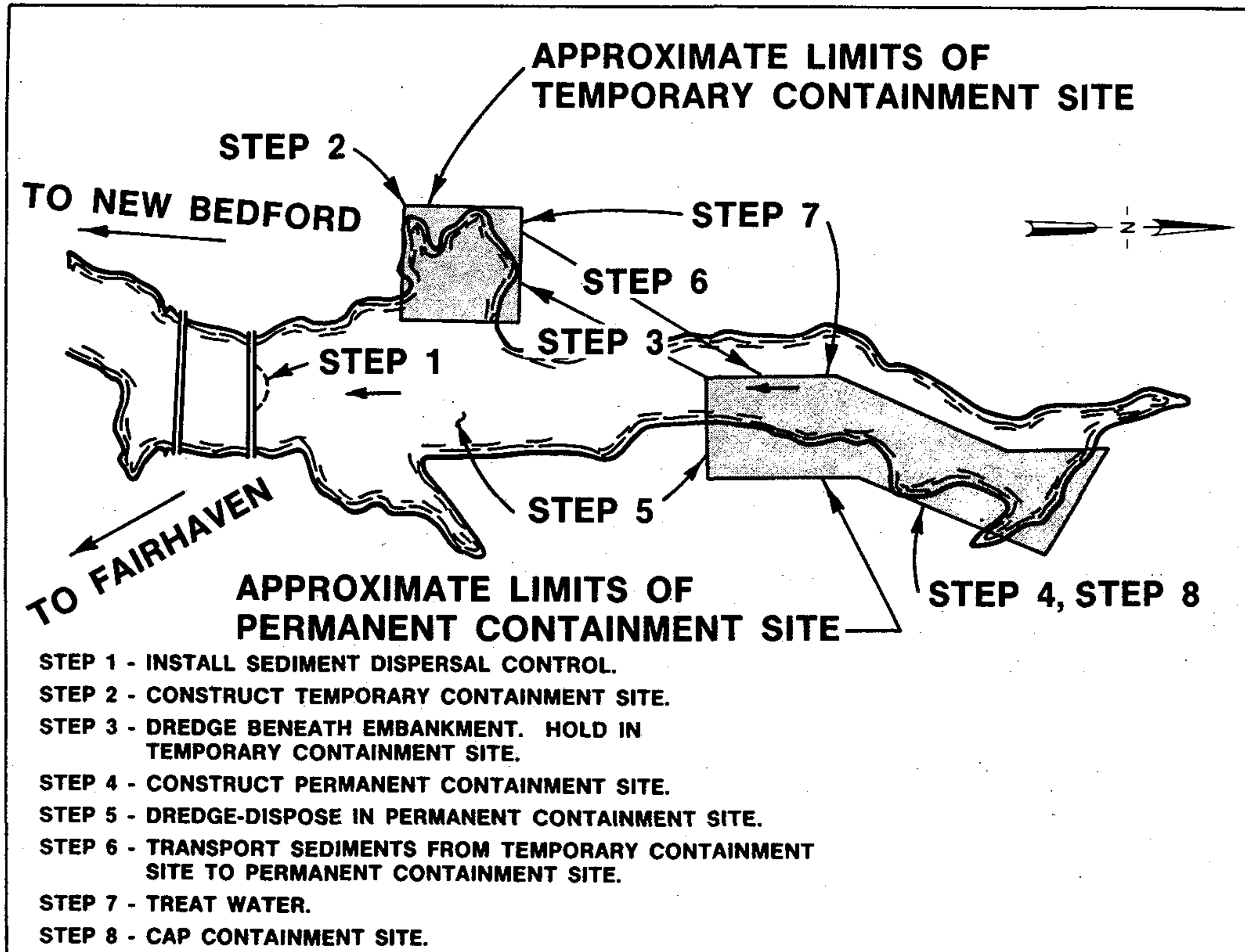


Figure 3. Concept for confined disposal alternative (NUS Corporation 1984a)

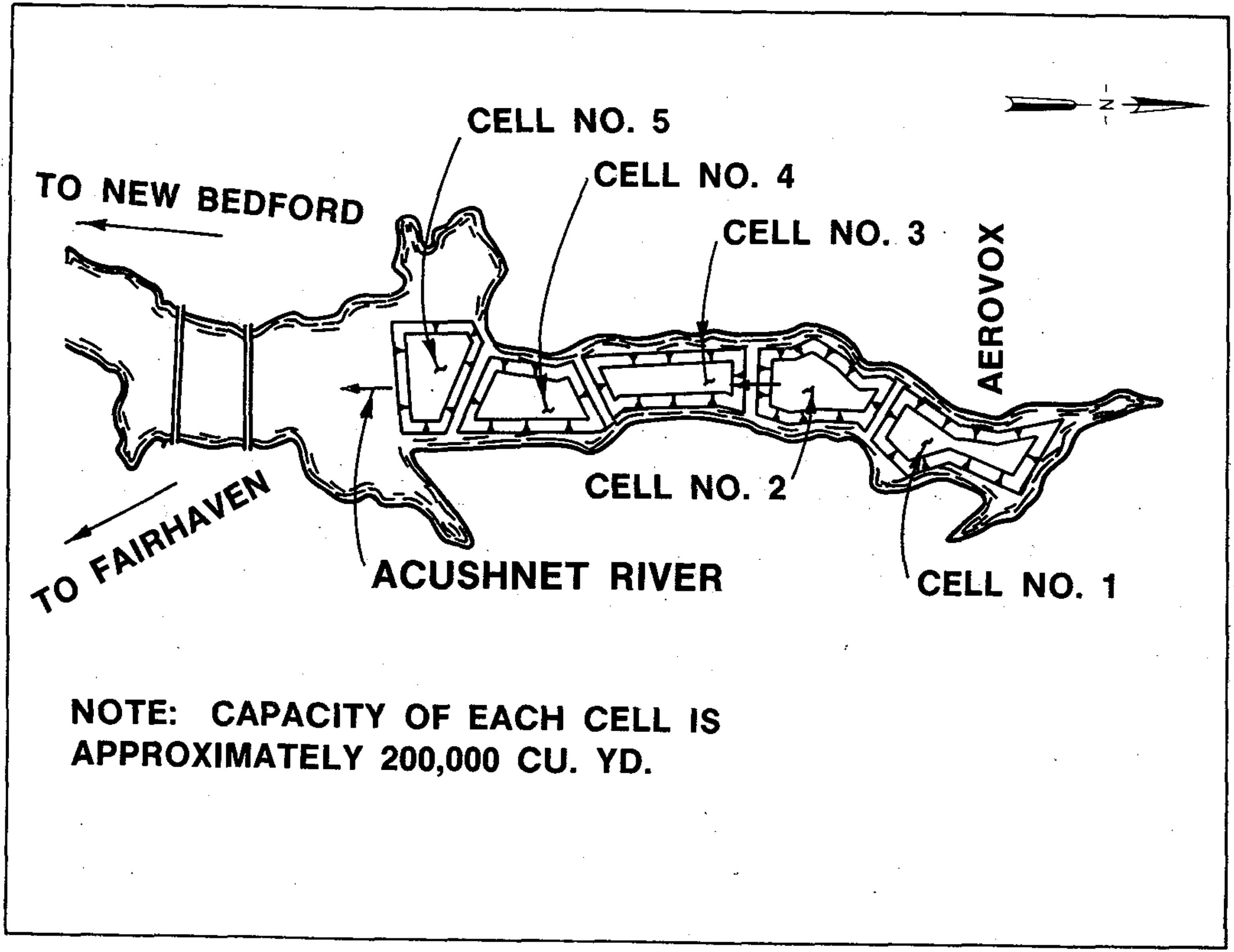


Figure 4. Concept for CAD alternative (NUS Corporation 1984b)

NONREMOVAL	REMOVAL	TREATMENT (SEDIMENT)	DISPOSAL
○ CAPPING	● MECHANICAL DREDGES	○ THERMAL	● IN-HARBOR
○ HYDRAULIC CONTROLS	• CLAMSHELL	∘ INCINERATION	● SHORELINE
∘ EARTHEN EMBANKMENTS	• WATERTIGHT CLAMSHELL	∘ SUPERCRITICAL WATER OXIDATION	● UPLAND
∘ SHEETPILE	● HYDRAULIC DREDGES	○ PHYSICAL	○ OFFSITE
○ SOLIDIFICATION	• CUTTERHEAD	∘ SOLVENT EXTRACTION	○ OCEAN
○ BIODEGRADATION	• PLAIN SUCTION	∘ SUPERCRITICAL FLUID EXTRACTION	
	• MATCHBOX SUCTION	∘ SOLIDIFICATION	
	• HOPPER	∘ VITRIFICATION	
	● SPECIAL-PURPOSE DREDGES	○ CHEMICAL	
	• CLEAN-UP	∘ ALKALI METAL DECHLORINATION	
	• REFRESHER	○ BIODEGRADATION	
	• AIRLIFT	(WATER)	
	• PNEUMA	○ DEWATERING	
	• OOZER	● TREATMENT	
	• MUDCAT	• FLOCCULATION	
	● EXCAVATION	• SEDIMENTATION	
	• DRAGLINE	• FILTRATION	
	• CLAMSHELL	• CARBON ADSORPTION	
	• WATERTIGHT CLAMSHELL	• UV/HYDROGEN PEROXIDE	

Figure 5. Feasibility study technologies for detailed evaluation (E. C. Jordan Company 1987) (darkened circles indicate the technologies evaluated in the USACE Engineering Feasibility Study)

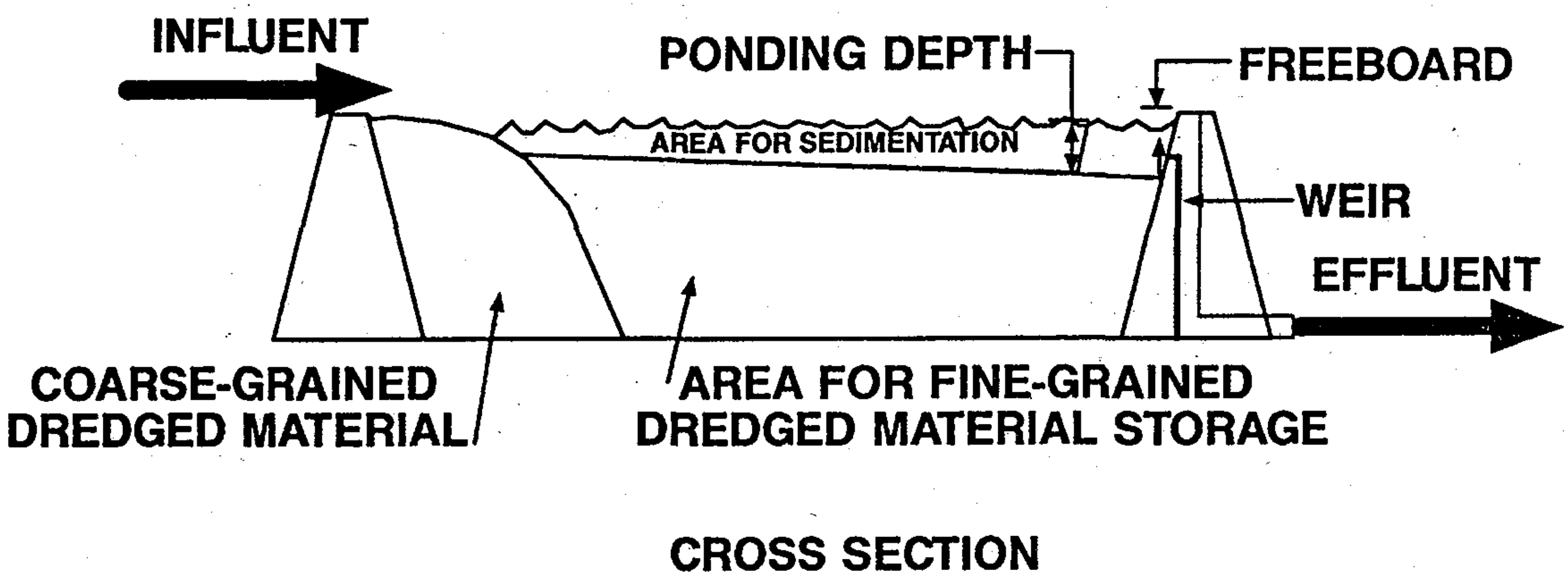


Figure 6. Components of a confined disposal facility

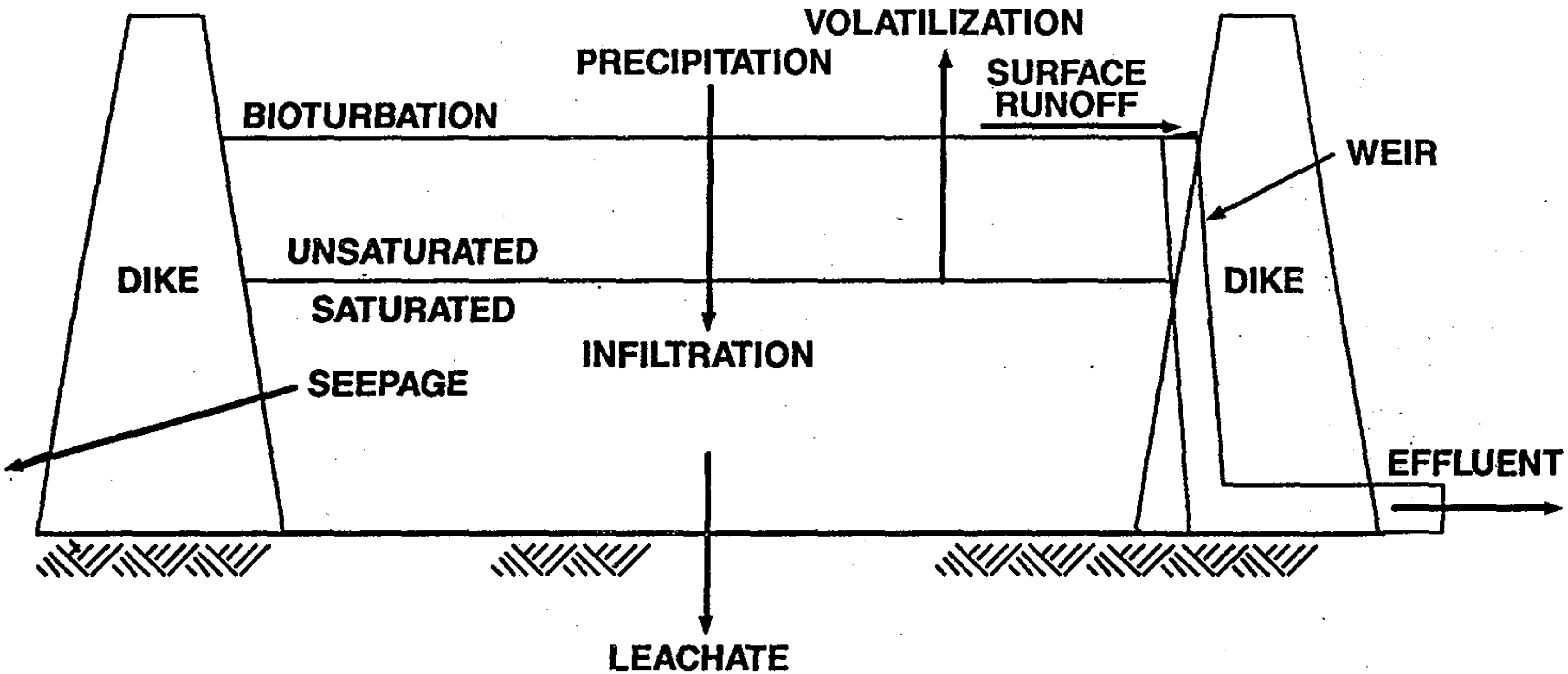


Figure 7. Contaminant migration pathways for an upland CDF

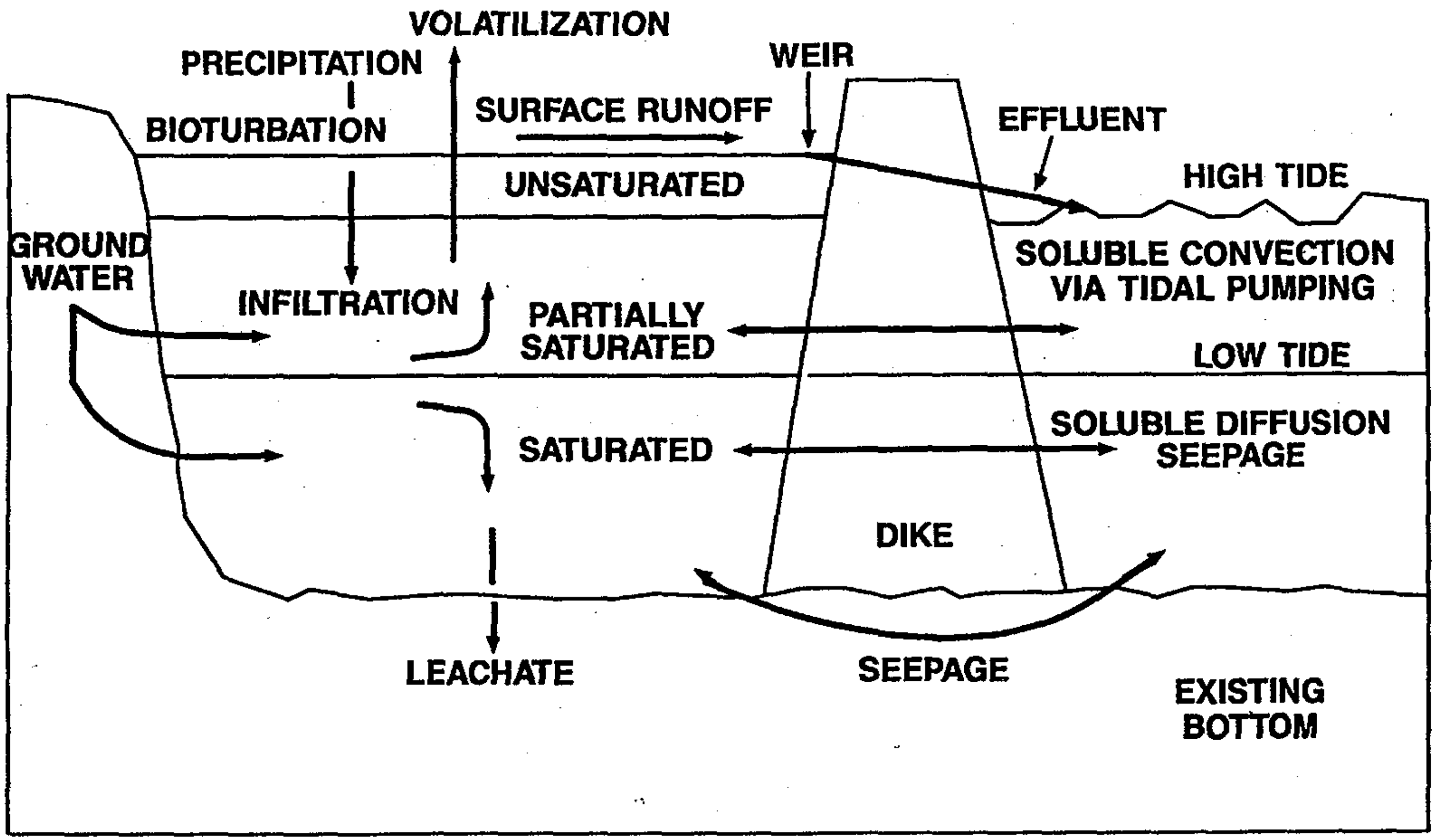


Figure 8. Contaminant migration pathways for a nearshore CDF

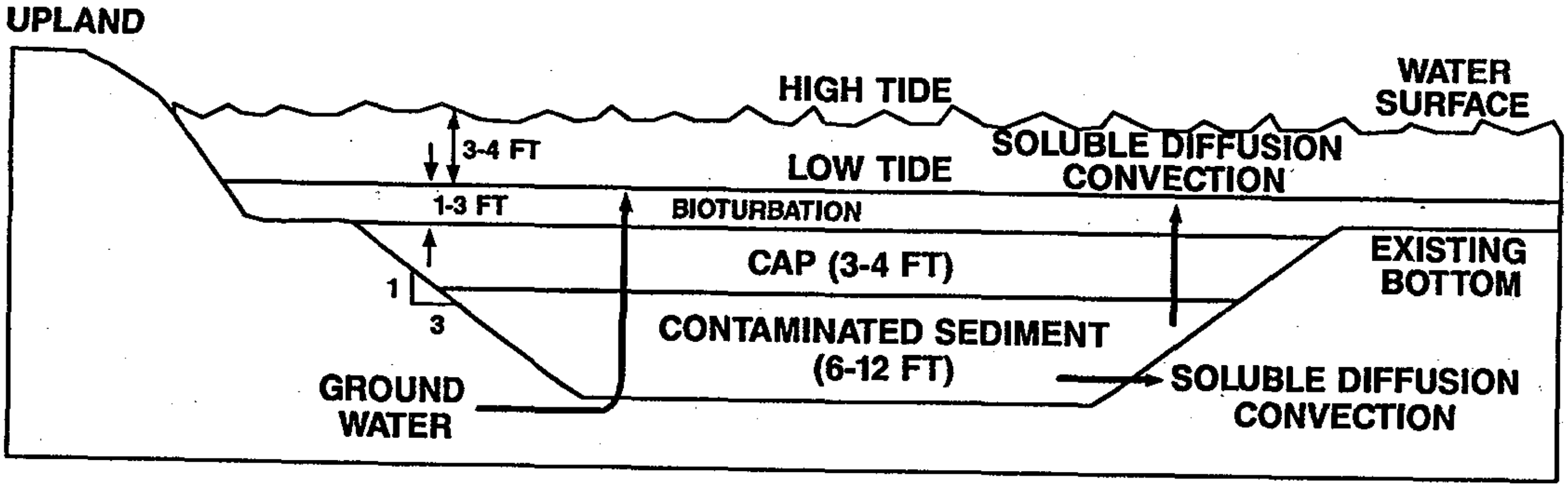


Figure 9. Contaminant migration pathways for CAD

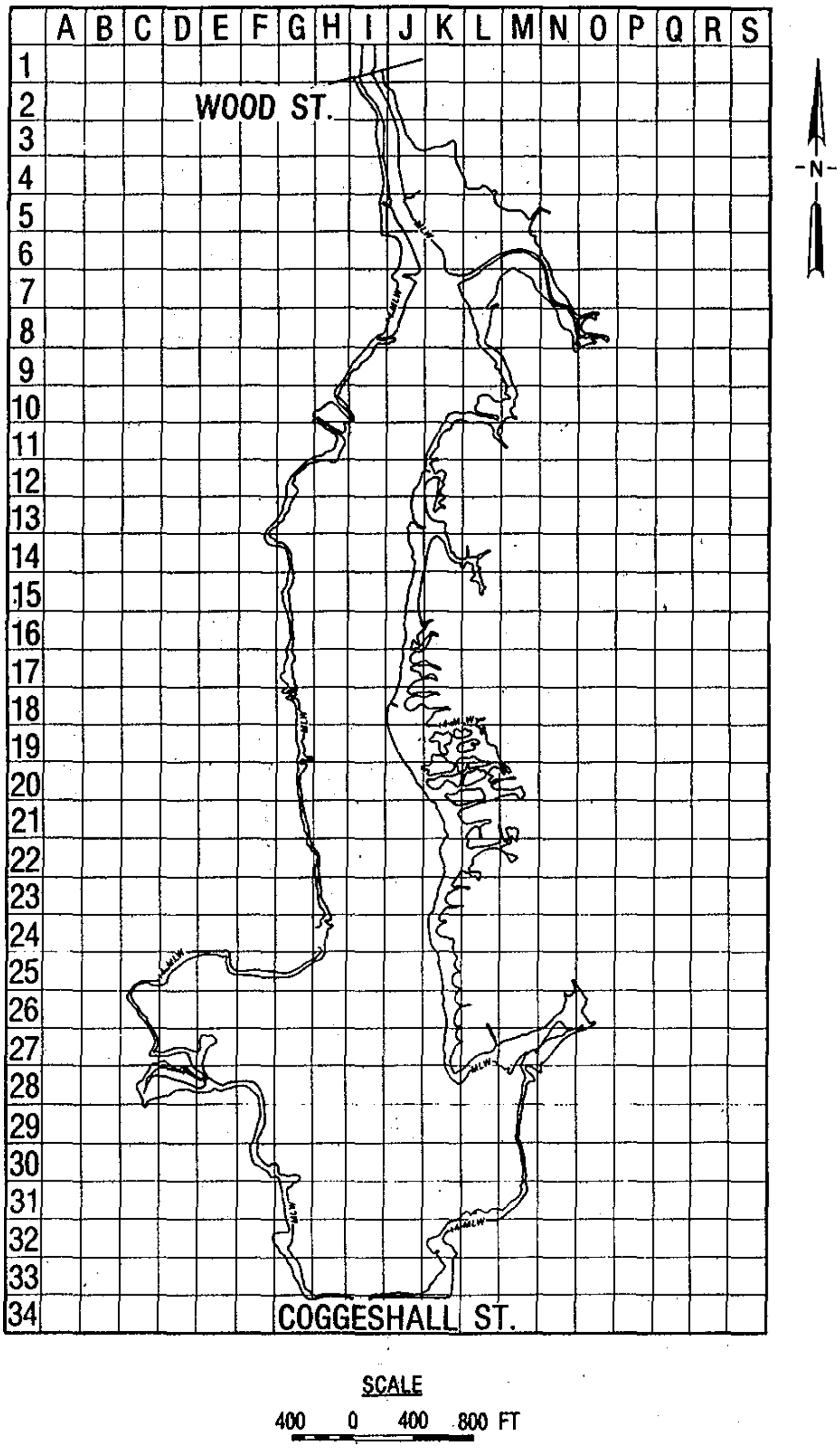


Figure 10. Upper Estuary grid system used in the EFS

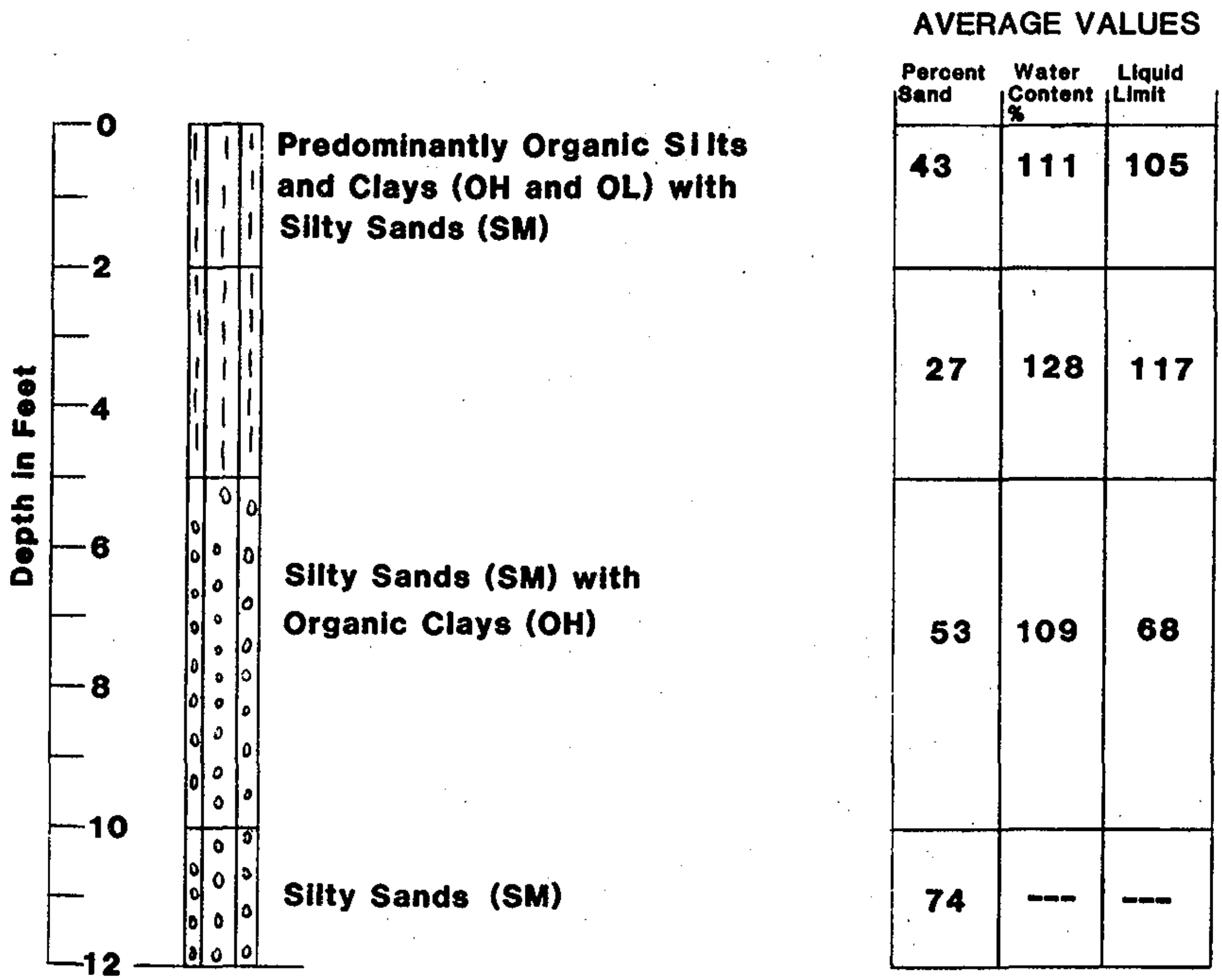


Figure 11. Average physical characteristics of estuary sediment

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3								938					
4													
5									282	440	550	440	
6									2843	22		607	7
7									52866	246			3
8								2884	2899	260		16	500
9								146	1227				
10							422	1750	7375	125	318		
11							2995	32750	574				
12						42	3157	1126	173	66			
13						80	1032	1475	139	1900			
14										161			
15								882	58				
16							240			2			
17						1147	376		139	0			
18						312	586	157		6			
19							509	657	445	1			
20						13	109	809	4	60	49		
21							448						
22							754	428					
23							332	441			67		
24							21	289					
25			34	109	10	67	205				2		
26			28	24	89	49	125			42		0	
27				27	70		60				26	52	
28						75	54	177		17			
29						26	27		8				
30													
31								22					
32							18			3			
33							2	83					

Figure 12. Sediment PCB concentrations, mg/kg, 0 to 1 ft

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3								0					
4													
5									282	2			
6									7			607	
7									18437				
8								71	624				
9									101				
10							19	4	3				
11							64	791					
12						1	936	28					
13							1	1	0				
14													
15								16					
16													
17						1			0				
18						1440	1201	2					
19							745	2					
20							1124	14					
21							2						
22								198					
23							2	441					
24							55	2					
25				2									
26										0			
27				27	2		2					0	
28						2	2			0			
29						2	2						
30													
31								0					
32										0			
33													

Figure 13. Sediment PCB concentrations, mg/kg, 1 to 2 ft

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								553*	530*				
3								938	553*				
4								905*	553*	424*	477*		
5								8234*	282	440	550	440	
6									2843	22	384*	607	7
7									52866	246	230*	226*	3
8								2884	2899	260	174*	16	500
9							1300*	146	1227	2377*	180*	278*	
10							422	1750	7375	125	318	214*	
11							2995	32750	574	1439*			
12						42	3157	1126	173	66			
13					1461*	80	1032	1475	139	1900			
14					937*	1004*	867*	717*	769*	161			
15						745*	557*	882	58				
16						588*	240	339*	216*	2			
17						1147	376	299*	139	0			
18						312	586	157	200*	6			
19						306*	509	657	445*	1			
20						13	109	809	4	60	49		
21						331*	448	425*	325*	38*			
22						511*	754	428	293*	262*			
23							332	441	386*	306*	67		
24							21	289	246*	181*			
25		44*	34	109	10	67	205	160*	146*	115*	2		
26		44*	28	24	89	49	125	130*	92*	42		0	
27		44*	26*	27	70	75*	60	104*	79*	28*	26	52	
28		26*	48*	48*	49*	75	54	177	67*	17	31*	27*	
29					48*	26	27	66*	8	50*	25*	31*	
30					40*	57*	25*	19*	41*	45*	9*	21*	
31						30*	27*	22	23*	29*	52*	9*	
32						31*	18	31*	36*	3			
33						31*	2	83	26*	36*			

Figure 14. Estimated sediment PCB concentrations, mg/kg, 0 to 1 ft (asterisk denotes the cell value was estimated from adjacent cells)

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								95*	95*				
3								0	95*				
4								73*	95*	180*	224*		
5								3746*	282	2	550		
6									7	22	384	607	7
7									18437	246	230	226	3
8								71	624	260	174		
9							31*	137*	101	243*	180	278	
10							19	4	3	125	243	214	
11							64	791	206*	133*			
12						1	936	28	173	66			
13					251*	80	1	1	0	167*			
14					313*	164*	6*	5*	6*				
15						5*	3*	16	4*				
16						532*	240	339	216				
17						1	376	299	0				
18						1440	1201	2	200				
19						306	745	2	6				
20						13	1124	14	4	54*			
21						316*	2	335*	316*	38			
22						230*	161*	198	230*	164*			
23							2	441	214*	214*			
24							55	2	116*	160*			
25		10*	10*	2	10	67*	84*	84*	84*	111*			
26		10*	10*	10*	10*	12*	11*	9*	10*	0			
27		10*	10*	27	2	2*	2	1*	1*	0*	0*	0	
28		10*	7*	8*	8*	2	2	2*	1*	0	0*	0	
29					5*	2	2	1*	1*	0*	0*	0	
30					2*	2*	1*	1*	1*	0*	0*	0	
31						1*	1*	0	1*	1*	0*	0	
32						1*	1*	1*	1*	0			
33						1	1	1	1	1			

Figure 15. Estimated sediment PCB concentrations, mg/kg, 1 to 2 ft (asterisk denotes the cell value was estimated from adjacent cells)

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								349	87				
3								261	349				
4								172	700	263	52		
5								208	357	333	567		
6									1509	17	417	613	0
7									48736	186	192	89	1
8								139	2203	232	87		
9							36	90	1097	2125	151	12	
10							86	1414	5960	110	267	38	
11							736	27343	1254	880			
12						21	2910	986	363	23			
13					51	76	998	1074	286	457			
14					22	807	839	1165	1347				
15						447	752	1192	70				
16						259	324	458	442				
17						496	306	405	123				
18						94	478	114	185				
19						68	370	479	1093				
20						4	116	589	8	63			
21						74	433	310	800	93			
22						11	664	343	721	658			
23							228	388	340	453			
24							11	255	217	247			
25		5	21	91	4	29	174	141	127	248			
26		24	31	26	79	45	136	114	260	92			
27		3	16	25	71	94	75	99	108	56	20	90	
28		2	15	23	37	85	61	181	92	40	66	29	
29					18	37	28	68	11	69	54	28	
30					12	68	26	20	56	62	19	22	
31						25	56	47	48	61	87	4	
32						21	38	66	76	2			
33						8	5	173	54	25			

Figure 16. Estimated PCB mass, kg, by grid cell, 0 to 1 ft

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								60	16				
3								0	60				
4								14	120	111	24		
5								95	357	2	567		
6									3	17	417	613	0
7									16997	186	192	88	1
8								3	474	232	87		
9							1	84	91	217	151	12	
10							4	3	2	110	204	38	
11							16	661	451	81			
12						1	863	24	363	23			
13					9	76	1	1	0	40			
14					7	132	6	7	10				
15						3	4	22	4				
16						234	324	458	442				
17						0	307	404	0				
18						435	980	1	184				
19						68	543	1	14				
20						4	1192	10	9	57			
21						70	2	244	777	93			
22						5	142	159	565	411			
23							1	388	188	316			
24							30	2	103	218			
25		1	6	2	4	29	71	74	73	240			
26		6	11	11	9	11	12	8	29	0			
27		1	6	25	2	3	3	1	2	0	0	0	
28		1	2	4	6	2	2	2	2	0	0	0	
29					2	2	2	1	2	0	0	0	
30					1	2	1	1	1	0	0	0	
31						1	3	1	2	2	0	0	
32						1	2	2	2	0			
33						0	2	2	2	1			

Figure 17. Estimated PCB mass, kg, by grid cell, 1 to 2 ft

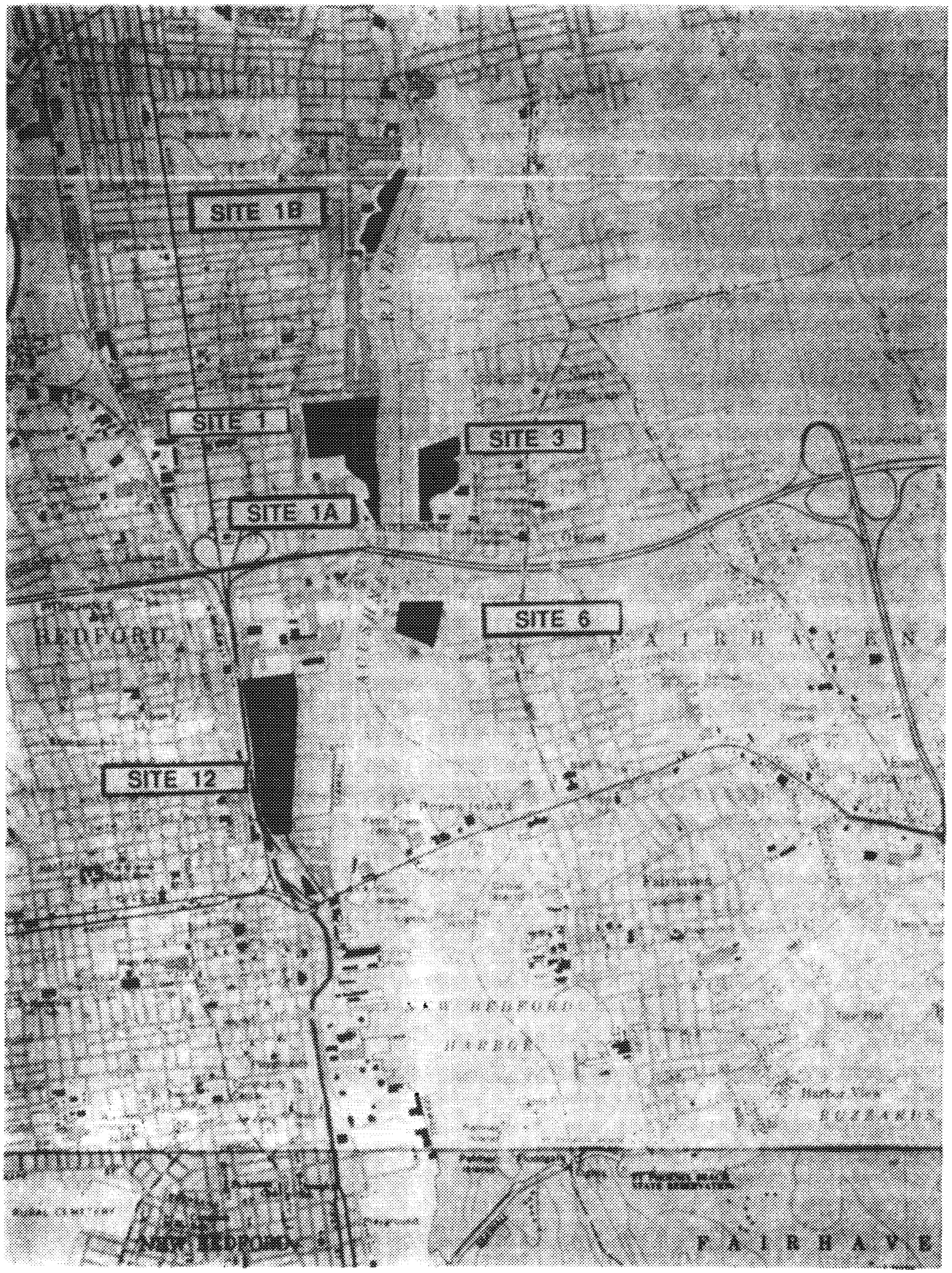
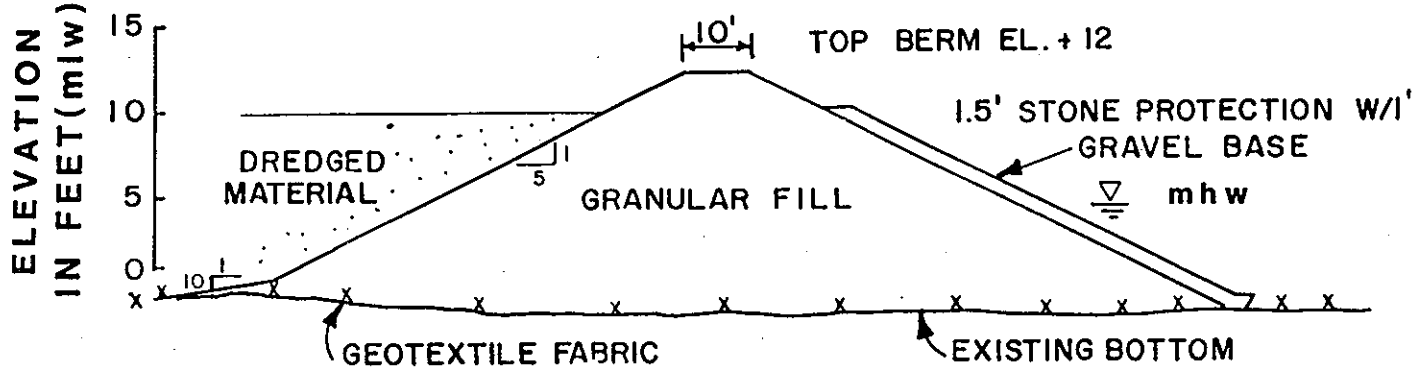
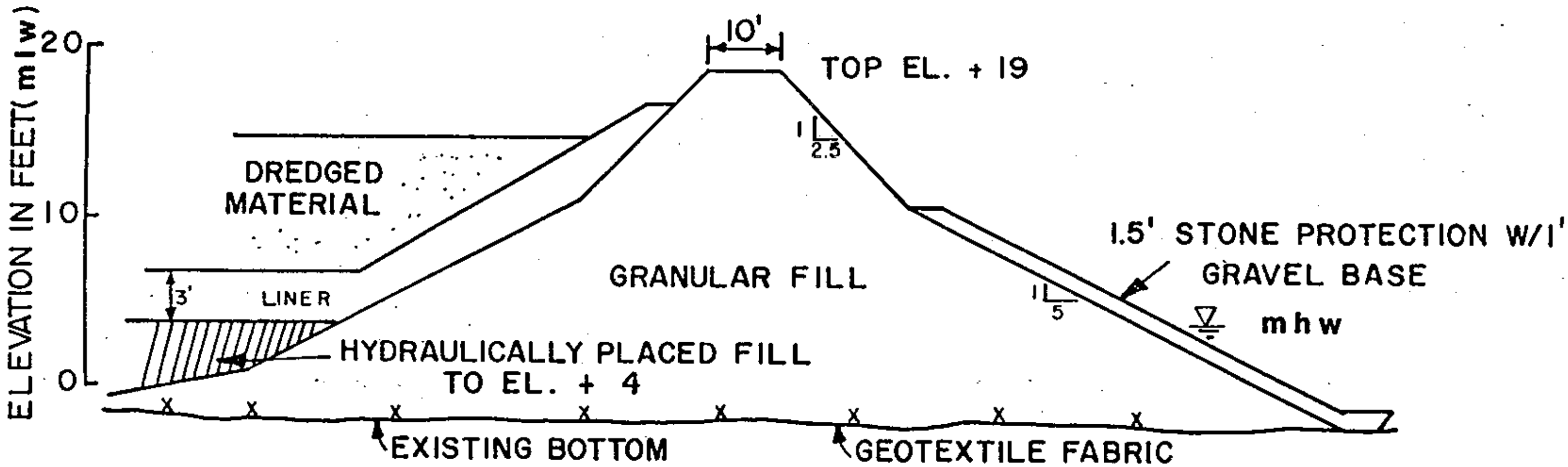


Figure 18. Locations of potential CDF sites

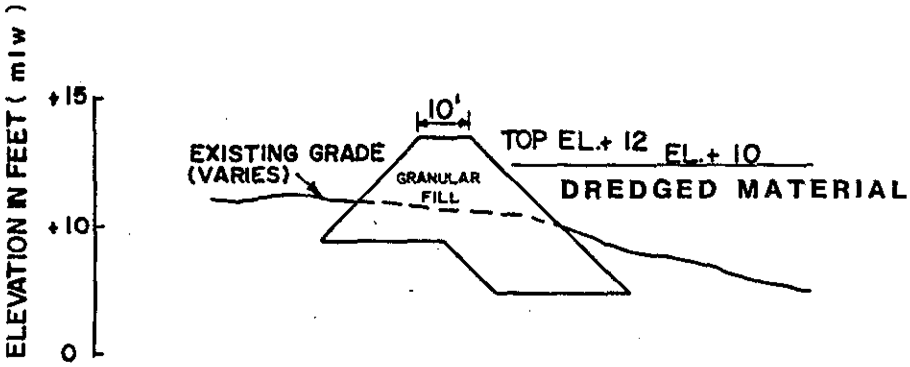


a. Typical in-water dike - unlined

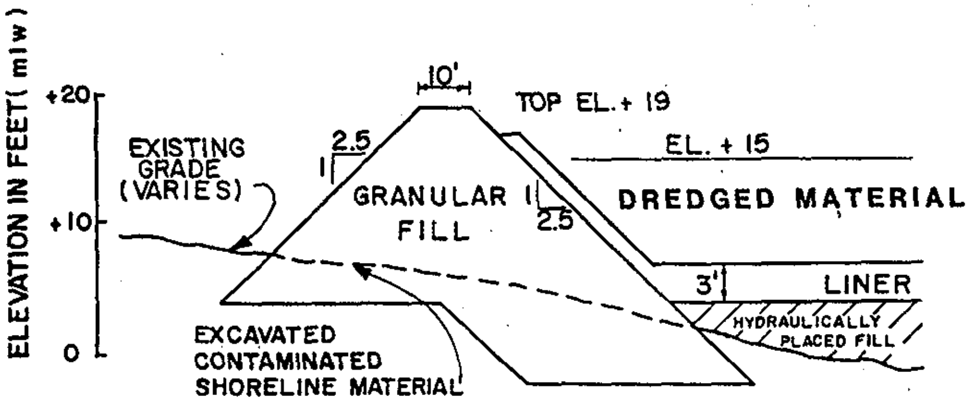


b. Typical in-water dike - lined

Figure 19. Site preparation requirements for installation of lined in-water dikes for sites 1, 1A, 1B, and 3



a. Typical land dike (site 1B) - unlined



b. Typical land dike (site 1B) - lined

Figure 20. Site preparation requirements for installation of lined land-side dikes for sites 1, 1A, 1B, and 3

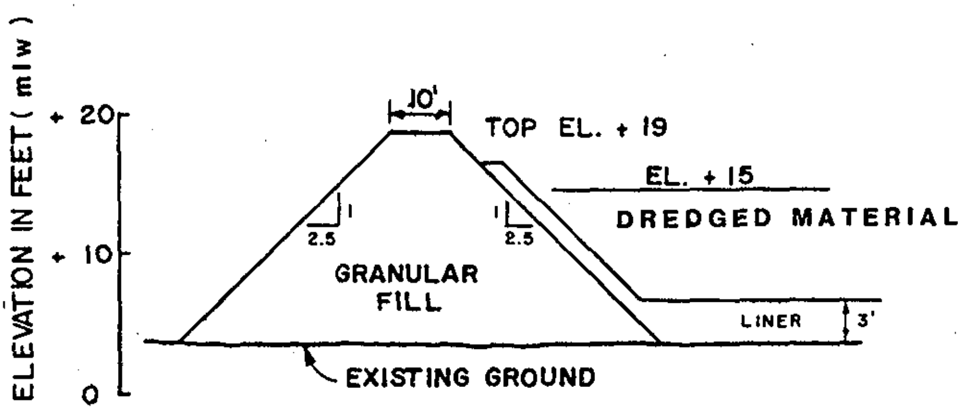


Figure 21. Design features for upland sites 6 and 12

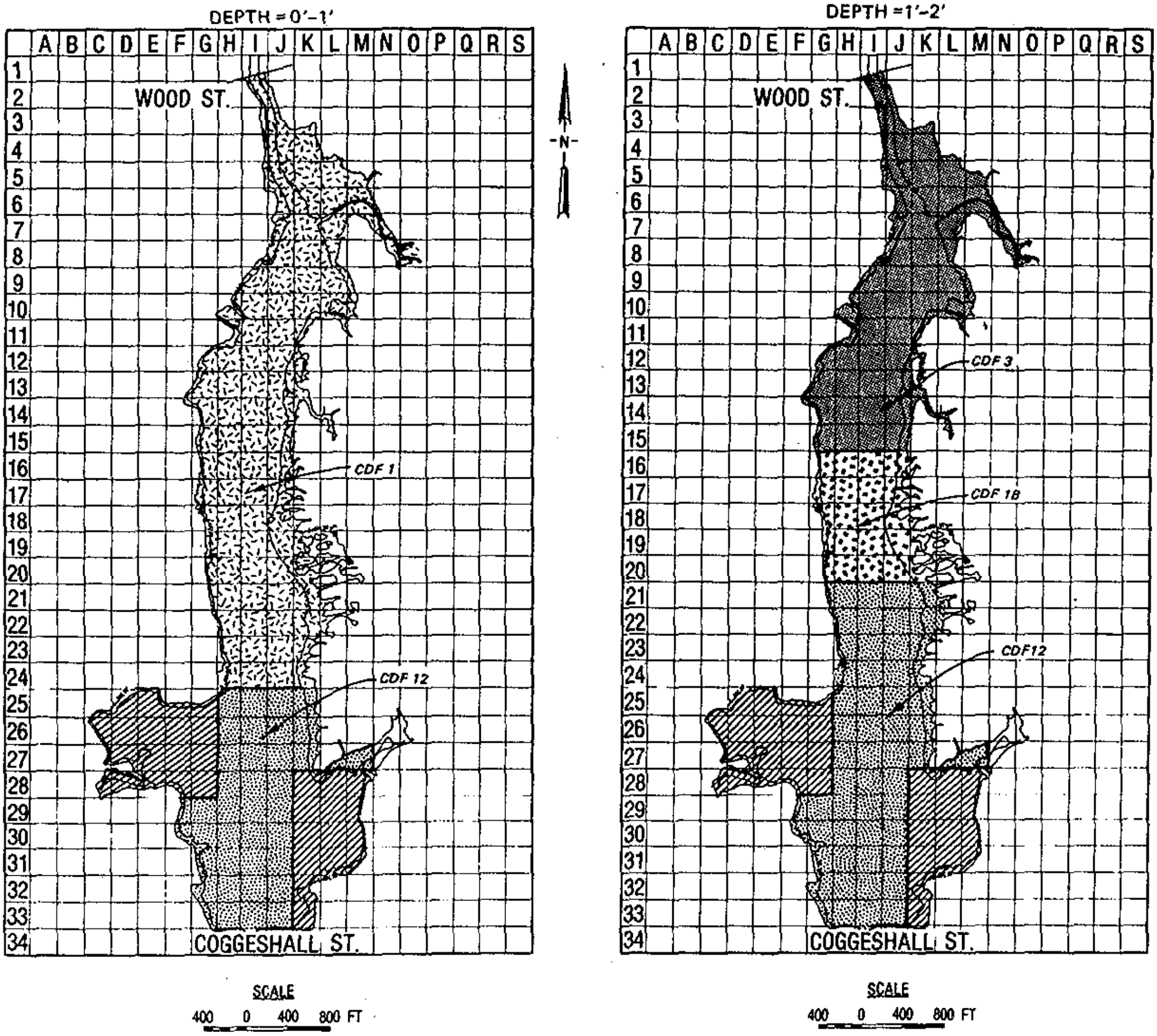


Figure 22. Sediment removal and placement in CDFs for CDF Option B

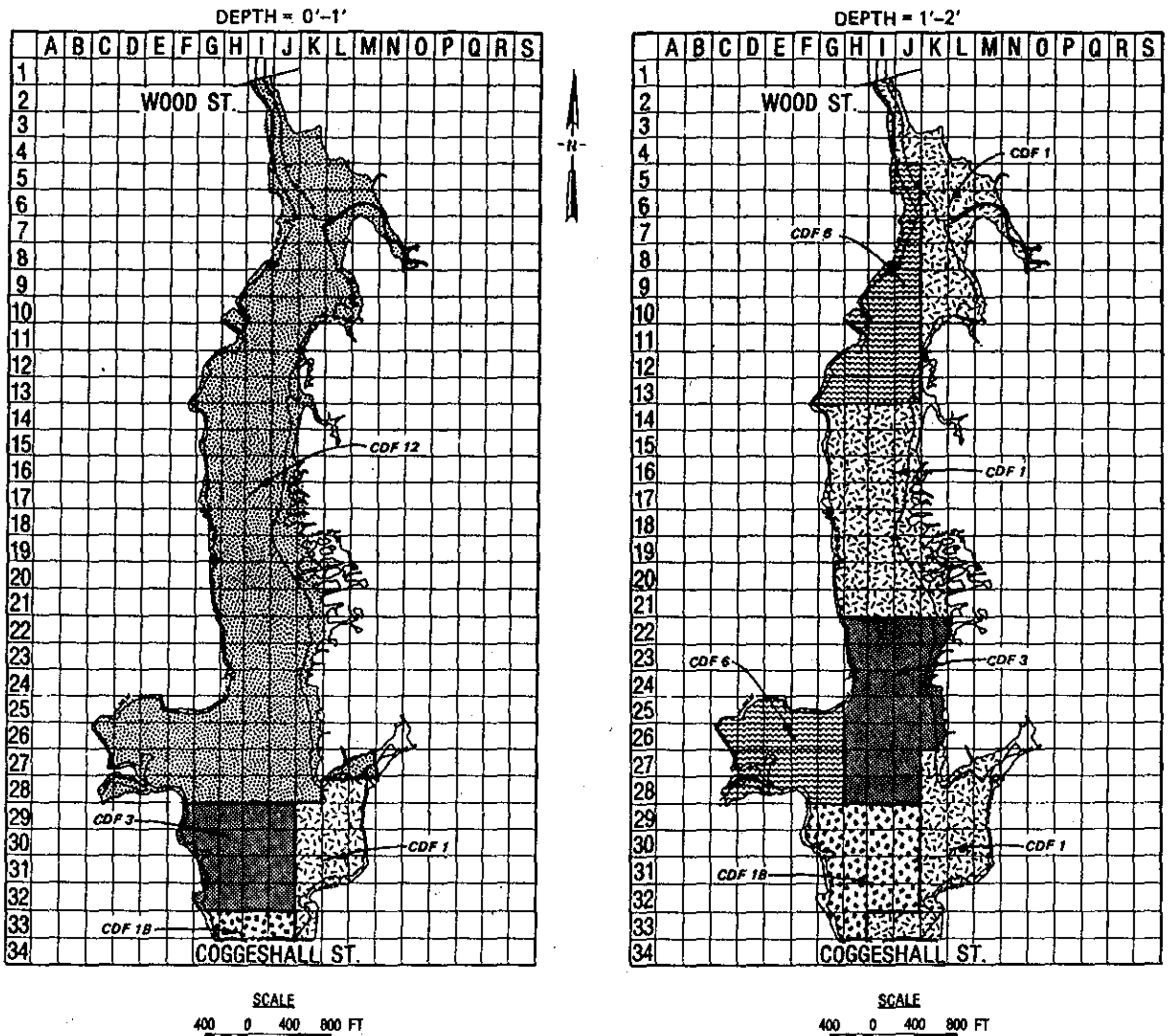


Figure 23. Sediment removal and placement in CDFs for CDF Option D

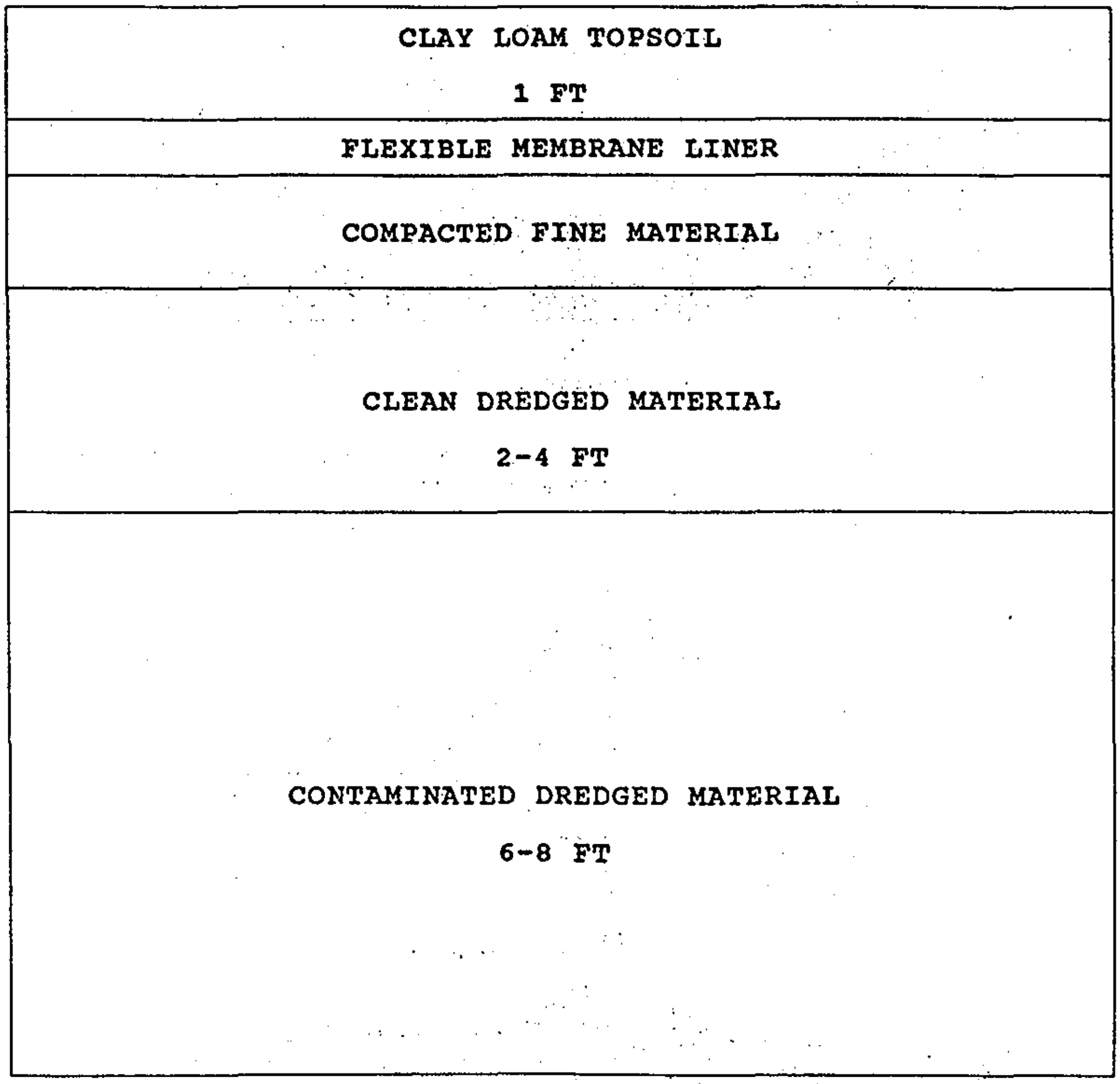


Figure 24. Typical CDF surface cover design

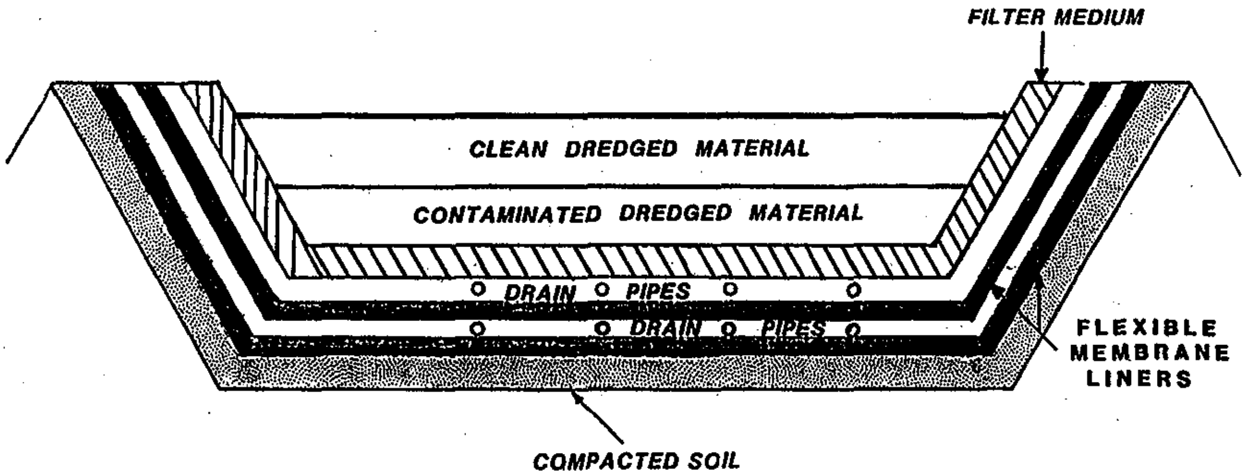


Figure 25. CDF double liner system with leachate collection above and below

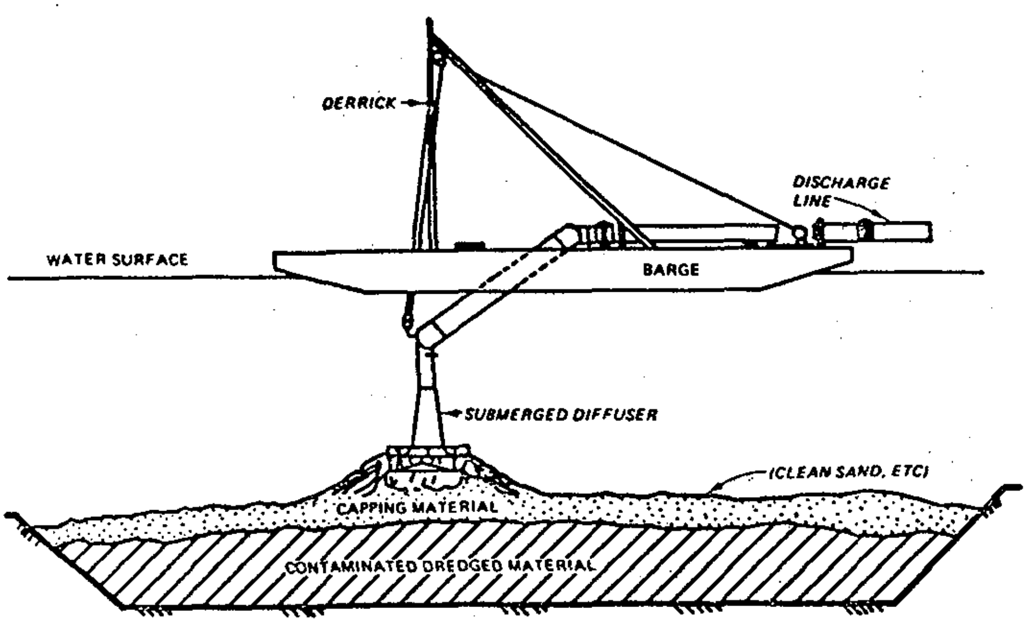


Figure 26. Concept of contained aquatic disposal

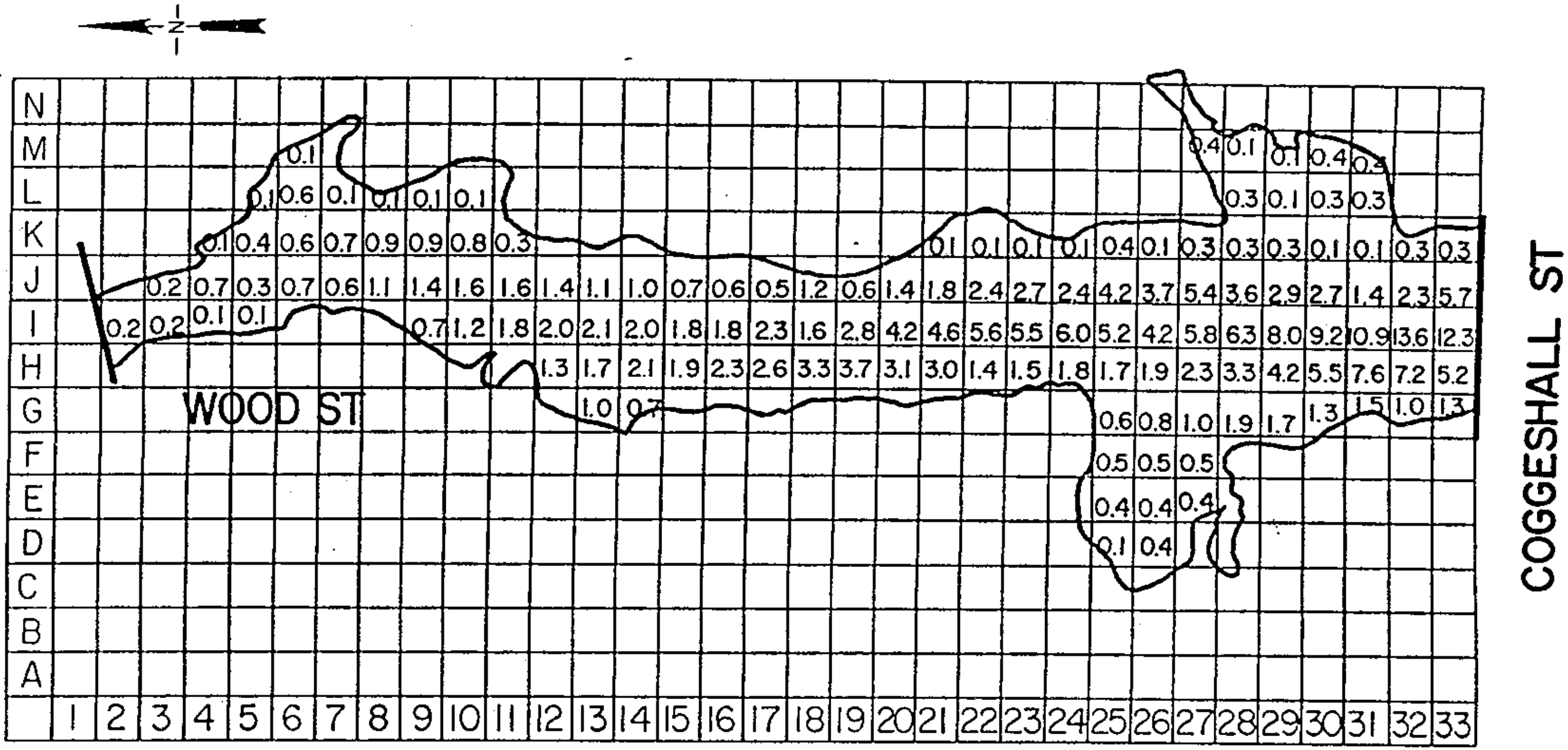


Figure 27. Average water depths (feet) at mean low water for Upper Estuary, New Bedford Harbor

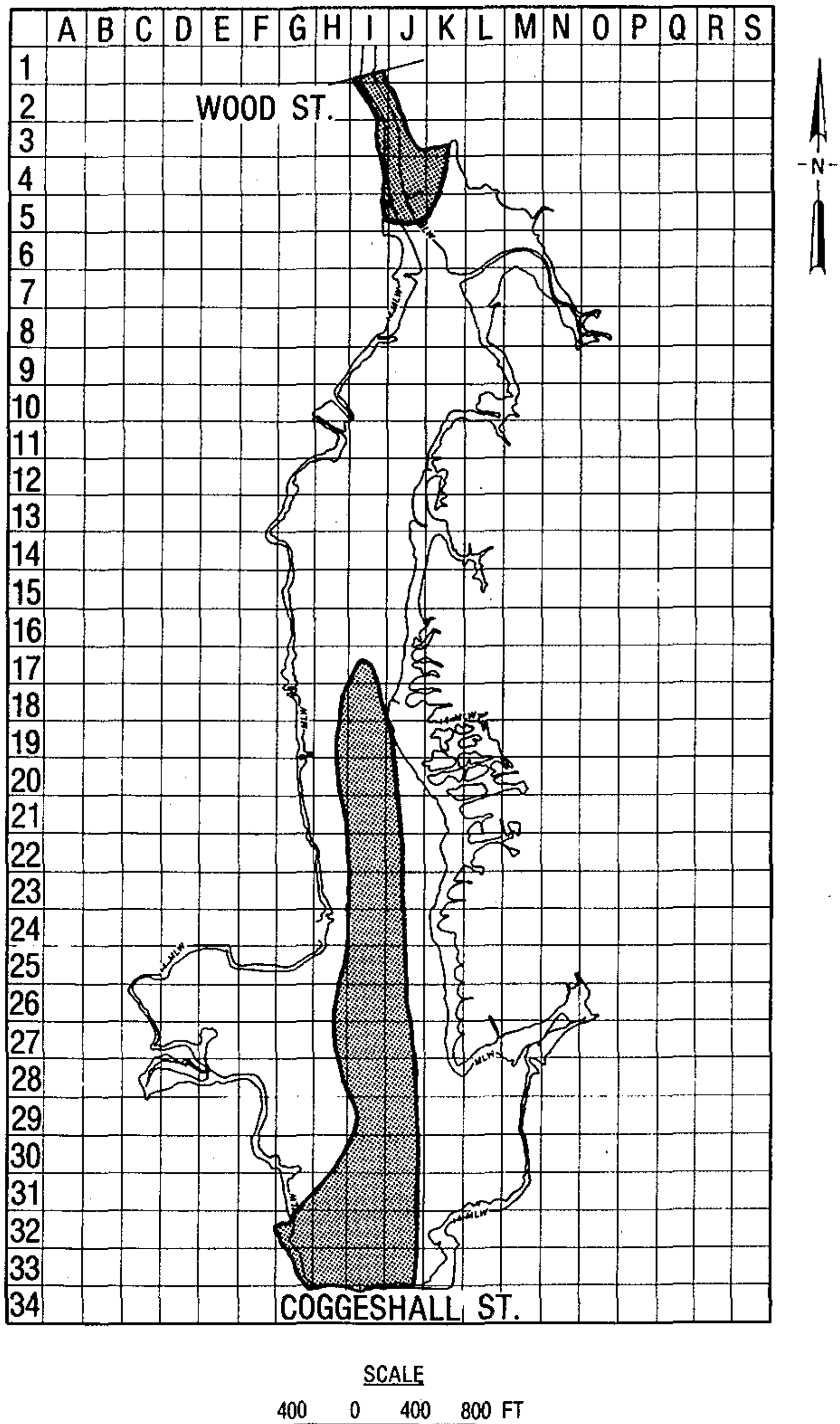


Figure 28. Exclusion zones for CAD

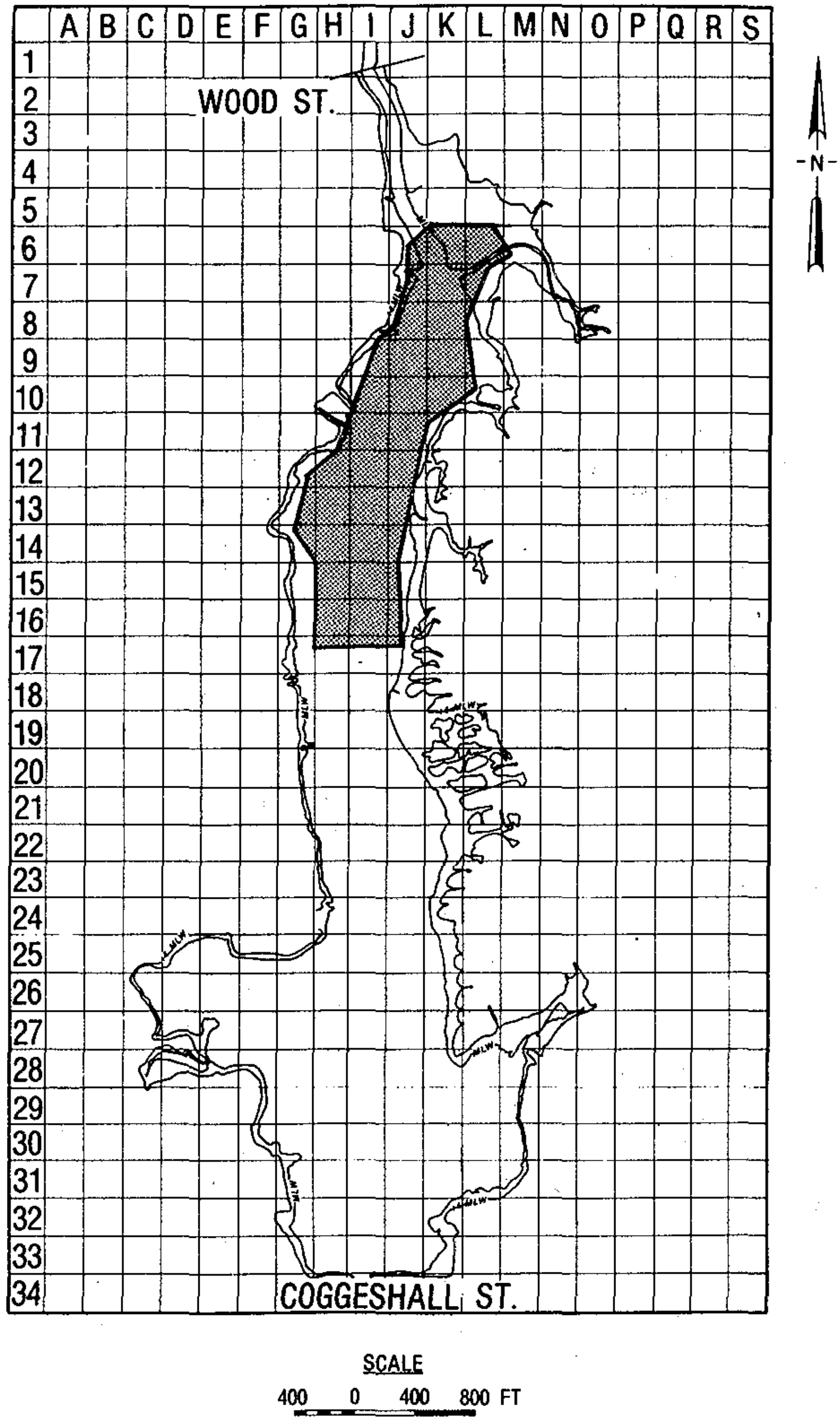


Figure 29. Cell configuration for CAD

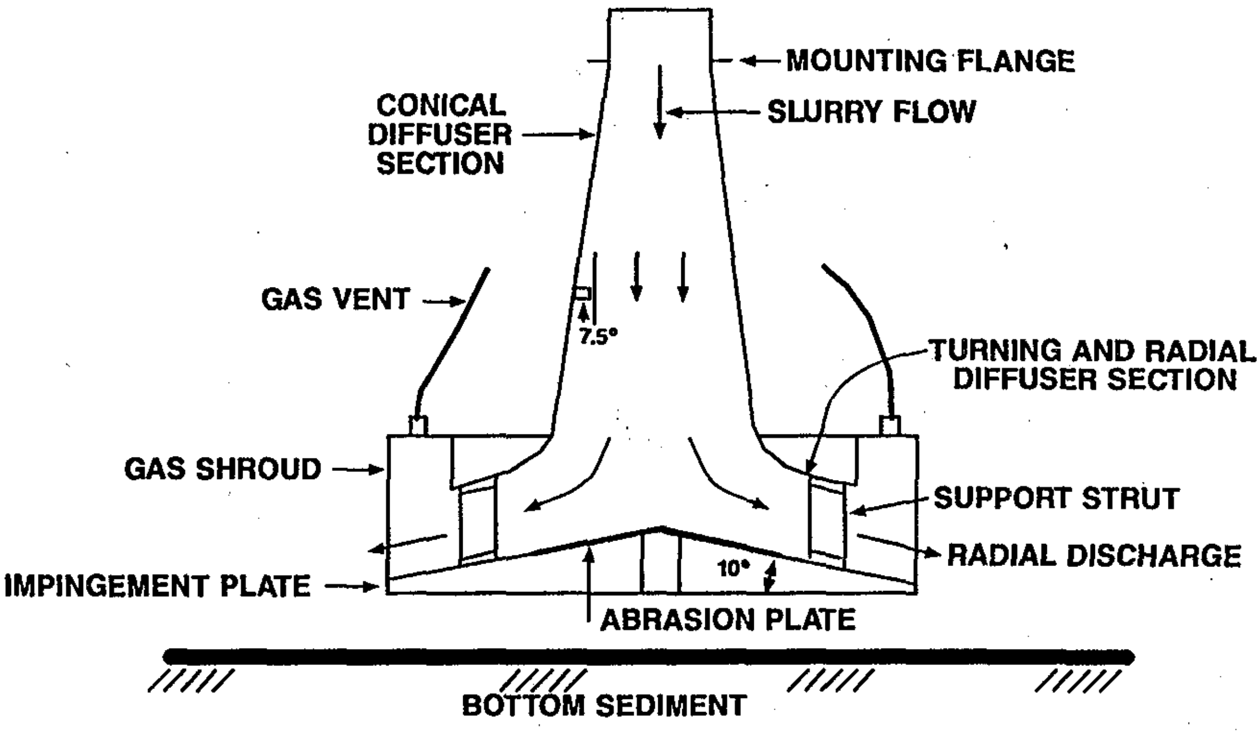


Figure 30. Submerged diffuser

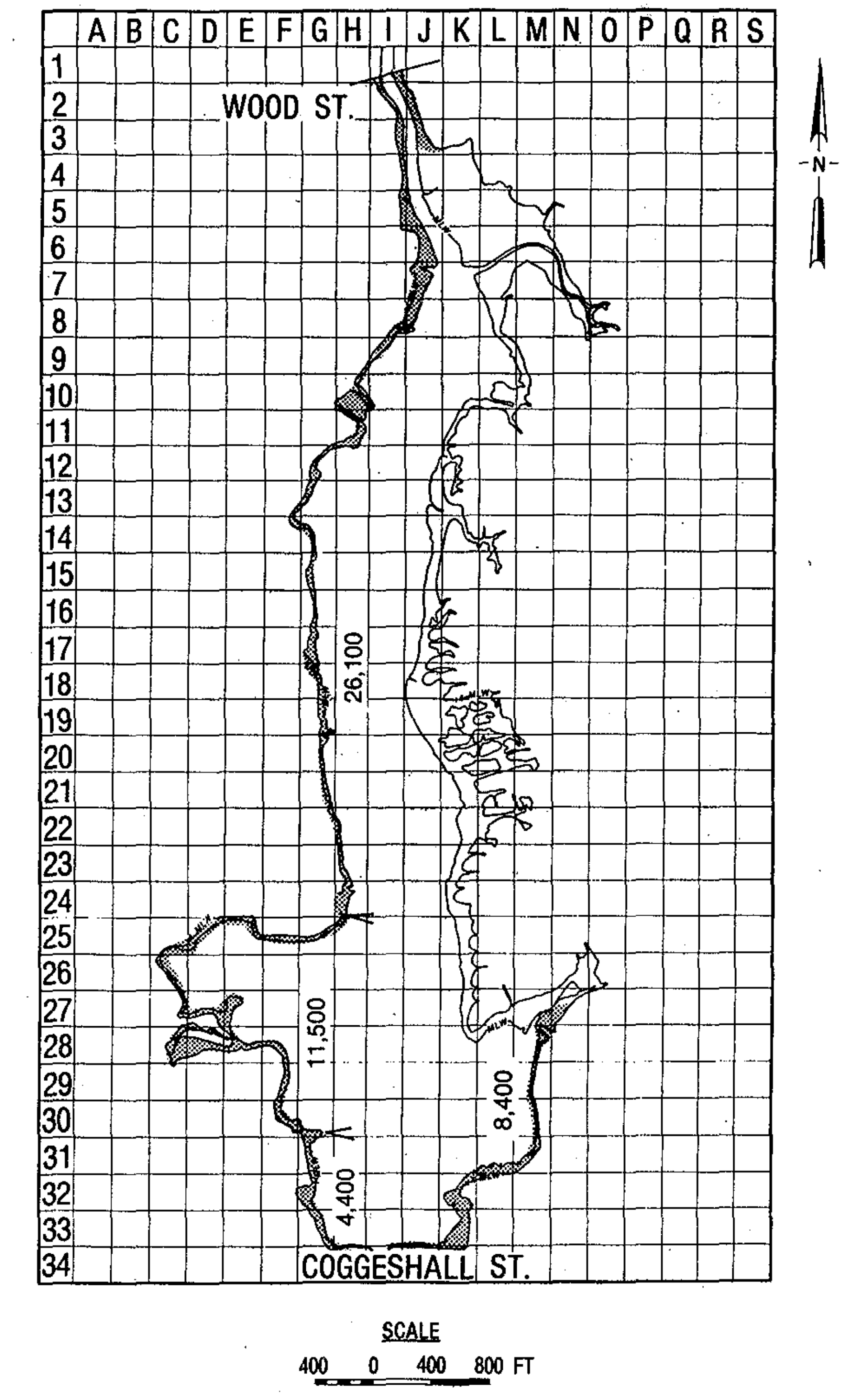


Figure 31. Volumes of material (cubic yards) adjacent to shoreline

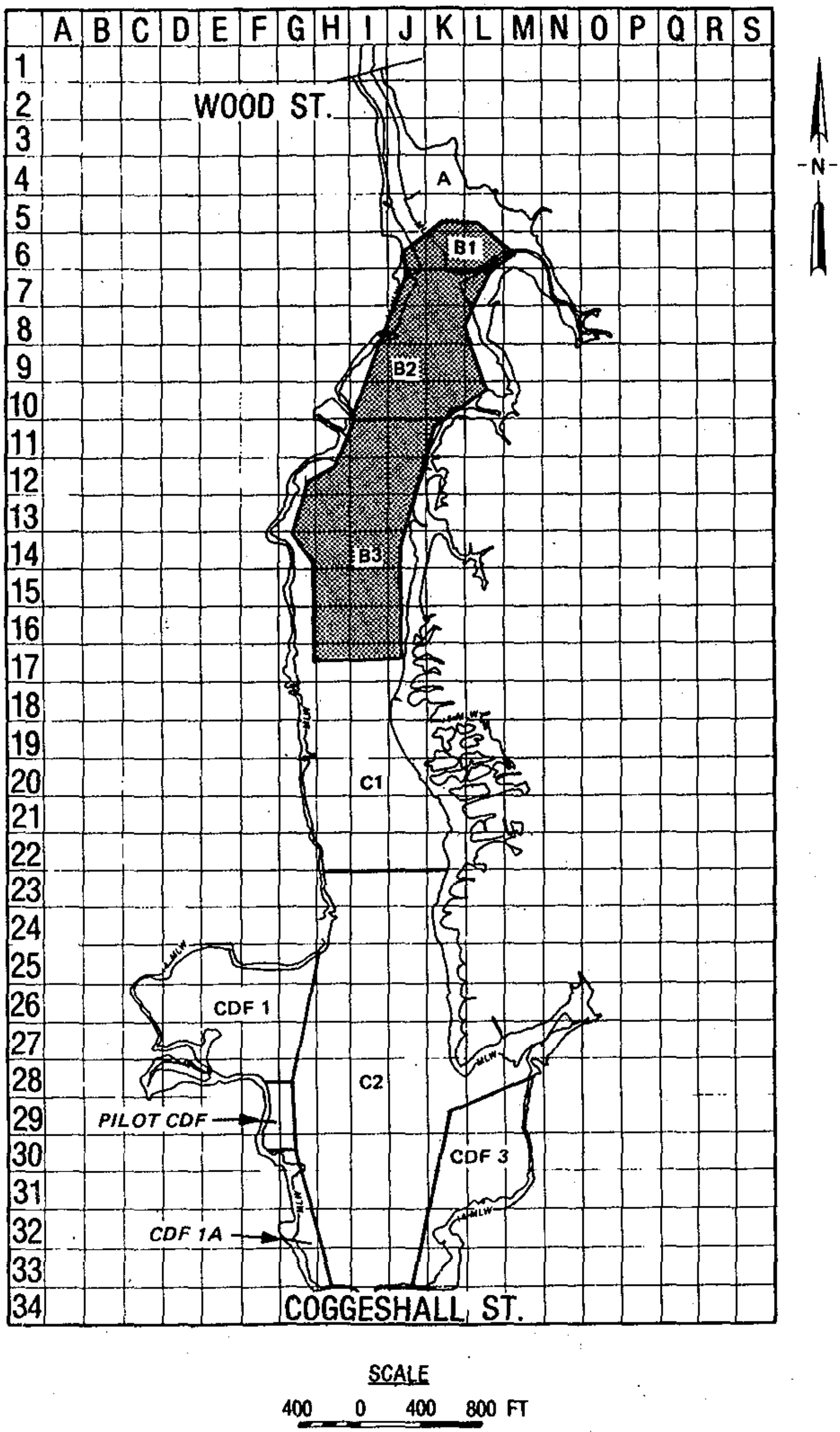


Figure 32. Layout of CDF and CAD sites for CAD option A

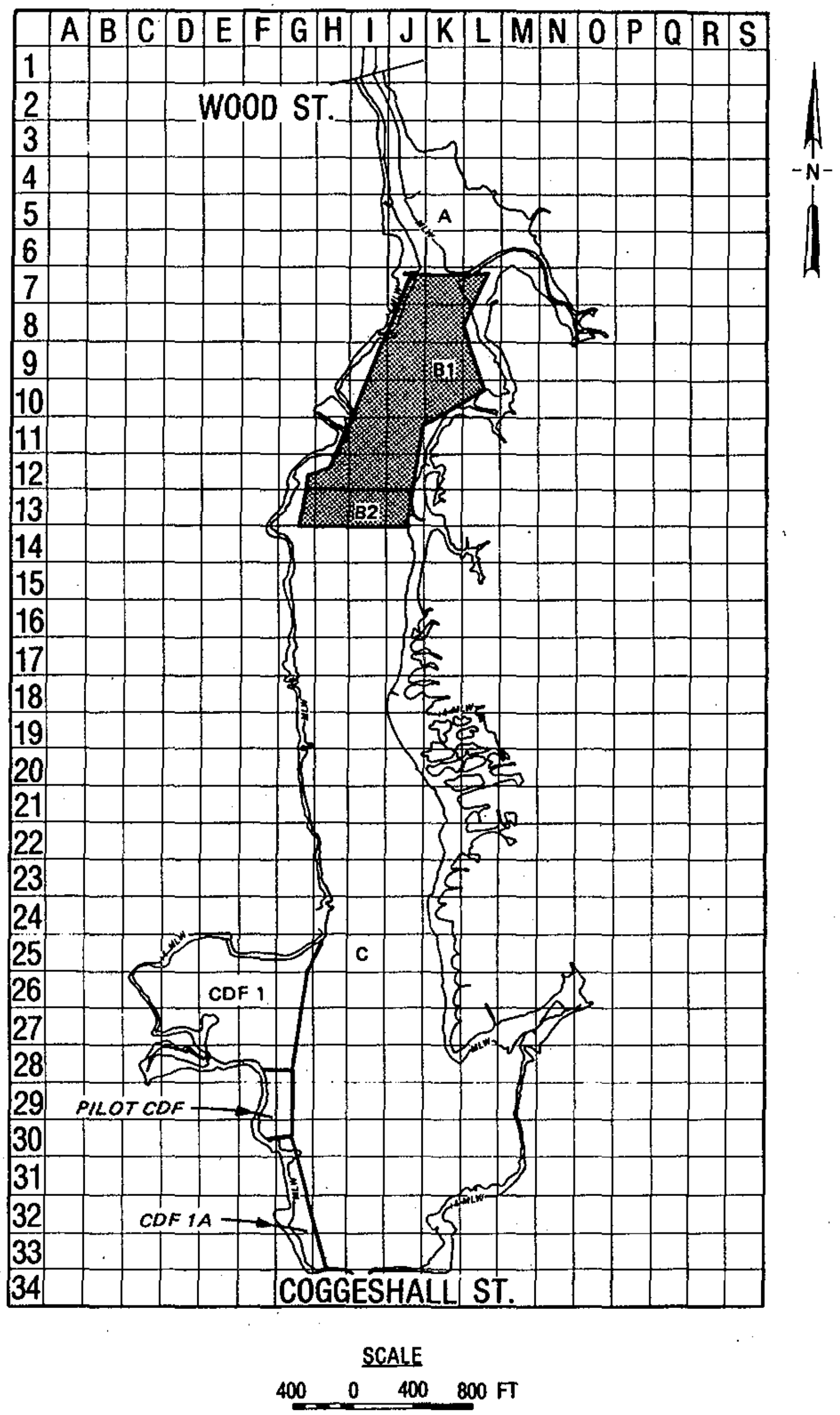


Figure 33. Layout of CDF and CAD sites for CAD option B

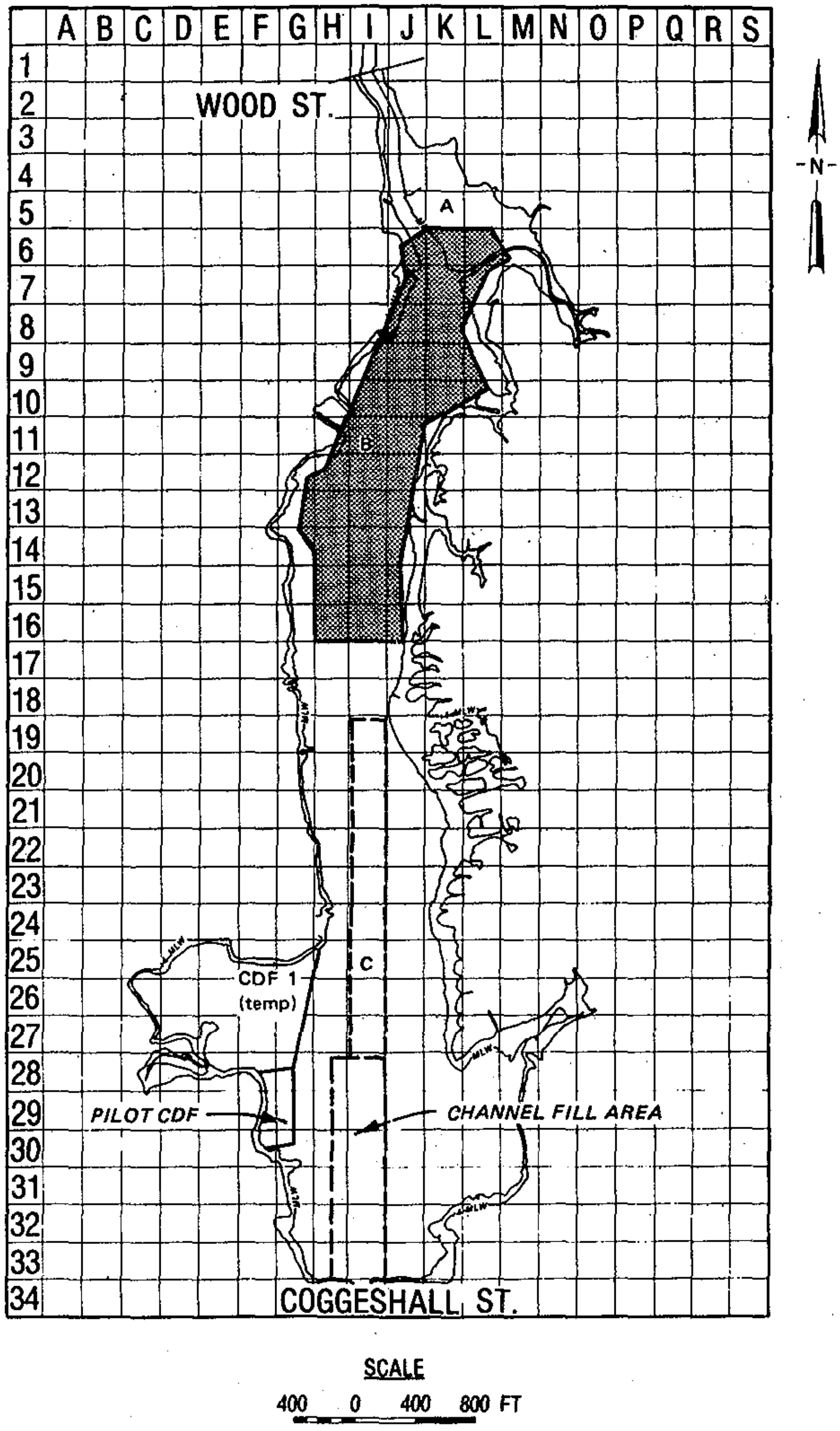


Figure 34. Layout of CDF and CAD sites for CAD option C

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2									*	*				
3									*	*				
4									*	*	*			
5									*	*	3	3		
6										3	3	3	3	*
7										3	3	3	*	*
8									*	3	3	3		
9								*	3	3	3	3	*	
10								*	3	3	3	3	*	
11								3	3	3	3	3		
12							3	3	3	3	*	3		
13						*	3	3	3	3	*	3		
14						*	3	3	3	3	*			
15							*	3	3	3				
16							*	3	3	3				
17							*	3	3	3				
18							*	*	*	*				
19							*	*	*	*				
20							*	*	*	*	*			
21							*	*	*	*	*			
22							*	*	*	*	*			
23								*	*	*	*			
24								*	*	*	*			
25			*	*	*	*	*	*	*	*	*			
26			*	*	*	*	*	*	*	*	*			
27			*	*	*	*	*	*	*	*	*	*	*	
28			*	*	*	*	*	*	*	*	*	*	*	
29						*	*	*	*	*	*	*	*	
30						*	*	*	*	*	*	*	*	
31							*	*	*	*	*	*	*	
32							*	*	*	*	*			
33							*	*	*	*	*			

Figure 35. Dredging depths in the 2- to 5-ft sediment layer, option A

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2									*	*				
3									*	*				
4									*	*	*			
5									*	*	5	5		
6										5	6	6	5	*
7										2	2	1	*	*
8									*	2	2	1		
9								*	1	2	2	1	*	
10								*	1	2	2	1	*	
11								4	4	5	4			
12							4	5	5	4	*			
13						*	4	5	5	4	*			
14						*	4	5	5	4	*			
15							*	4	5	4				
16							*	4	5	4				
17							*	4	4	4				
18							*	*	*	*				
19							*	*	*	*				
20							*	*	*	*	*			
21							*	*	*	*	*			
22							*	*	*	*	*			
23								*	*	*	*			
24								*	*	*	*			
25			*	*	*	*	*	*	*	*	*			
26			*	*	*	*	*	*	*	*	*			
27			*	*	*	*	*	*	*	*	*	*	*	
28			*	*	*	*	*	*	*	*	*	*	*	
29						*	*	*	*	*	*	*	*	
30						*	*	*	*	*	*	*	*	
31							*	*	*	*	*	*	*	
32							*	*	*	*	*			
33							*	*	*	*	*			

Figure 36. Dredging depths in the 5- to 10-ft sediment layer, option A

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2									*	*				
3									*	*				
4									*	*	*			
5									*	*	0	0		
6										3	3	3	3	*
7										3	3	3	*	*
8									*	3	3	3		
9								*	3	3	3	3	*	
10								*	3	3	3	3	*	
11								3	3	3	3			
12							3	3	3	3	*			
13						*	3	3	3	3	*			
14						*	0	0	0	0	*			
15							*	0	0	0				
16							*	0	0	0				
17							*	0	0	0				
18							*	*	*	*				
19							*	*	*	*				
20							*	*	*	*	*			
21							*	*	*	*	*			
22							*	*	*	*	*			
23								*	*	*	*			
24								*	*	*	*			
25			*	*	*	*	*	*	*	*	*			
26			*	*	*	*	*	*	*	*	*			
27			*	*	*	*	*	*	*	*	*	*	*	
28			*	*	*	*	*	*	*	*	*	*	*	
29						*	*	*	*	*	*	*	*	
30						*	*	*	*	*	*	*	*	
31							*	*	*	*	*	*	*	
32							*	*	*	*	*			
33							*	*	*	*	*			

Figure 37. Dredging depths in the 2- to 5-ft sediment layer, option B

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2									*	*				
3									*	*				
4									*	*	*			
5									*	*	0	0		
6										5	5	5	5	*
7										5	5	5	*	*
8									*	5	5	5		
9								*	5	5	5	5	*	
10								*	5	5	5	5	*	
11								5	5	5	5			
12							5	5	5	5	5			
13						*	5	5	5	5	*			
14						*	0	0	0	0	*			
15							*	0	0	0				
16							*	0	0	0				
17							*	0	0	0				
18							*	*	*	*				
19							*	*	*	*				
20							*	*	*	*	*			
21							*	*	*	*	*			
22							*	*	*	*	*			
23								*	*	*	*			
24								*	*	*	*			
25			*	*	*	*	*	*	*	*	*			
26			*	*	*	*	*	*	*	*	*			
27			*	*	*	*	*	*	*	*	*	*	*	
28			*	*	*	*	*	*	*	*	*	*	*	
29						*	*	*	*	*	*	*	*	
30						*	*	*	*	*	*	*	*	
31							*	*	*	*	*	*	*	
32							*	*	*	*	*			
33							*	*	*	*	*			

Figure 38. Dredging depths in the 5- to 10-ft sediment layer, option B

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2									*	*				
3									*	*				
4									*	*	*			
5									*	*	0	0		
6										4	4	4	4	*
7										4	4	4	*	*
8									*	4	5	4		
9								*	4	5	5	4	*	
10								*	4	5	5	4	*	
11								4	5	5	4			
12							4	4	4	4	4			
13						*	4	4	4	4	*			
14						*	0	0	0	0	*			
15							*	0	0	0				
16							*	0	0	0				
17							*	0	0	0				
18							*	*	*	*				
19							*	*	*	*				
20							*	*	*	*	*			
21							*	*	*	*	*			
22							*	*	*	*	*			
23								*	*	*	*			
24								*	*	*	*			
25			*	*	*	*	*	*	*	*	*			
26			*	*	*	*	*	*	*	*	*			
27			*	*	*	*	*	*	*	*	*	*	*	
28			*	*	*	*	*	*	*	*	*	*	*	
29						*	*	*	*	*	*	*	*	
30						*	*	*	*	*	*	*	*	
31							*	*	*	*	*	*	*	
32							*	*	*	*	*			
33							*	*	*	*	*			

Figure 39. Dredging depths in the sediment layer below 10 ft, option B

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2									*	*				
3									*	*				
4									*	*	*			
5									*	*	0	0		
6										3	3	3	3	*
7										3	3	3	*	*
8									*	3	3	3		
9								*	3	3	3	3	*	
10								*	3	3	3	3	*	
11								3	3	3	3			
12							3	3	3	3	*			
13						*	3	3	3	3	*			
14						*	3	3	3	3	*			
15							*	3	3	3				
16							*	3	3	3				
17							*	0	0	0				
18							*	*	*	*				
19							*	*	*	*				
20							*	*	*	*	*			
21							*	*	*	*	*			
22							*	*	*	*	*			
23								*	*	*	*			
24								*	*	*	*			
25			*	*	*	*	*	*	*	*	*			
26			*	*	*	*	*	*	*	*	*			
27			*	*	*	*	*	*	*	*	*	*	*	
28			*	*	*	*	*	*	*	*	*	*	*	
29						*	*	*	*	*	*	*	*	
30						*	*	*	*	*	*	*	*	
31							*	*	*	*	*	*	*	
32							*	*	*	*	*			
33							*	*	*	*	*			

Figure 40. Dredging depths in the 2- to 5-ft sediment layer, option C

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2									*	*				
3									*	*				
4									*	*	*			
5									*	*	0	0		
6										5	5	5	5	*
7										5	5	5	*	*
8									*	5	5	5		
9								*	5	5	5	5	*	
10								*	5	5	5	5	*	
11								5	5	5	5			
12							5	5	5	5	5			
13						*	5	5	5	5	*			
14						*	5	5	5	5	*			
15							*	5	5	5				
16							*	5	5	5				
17							*	0	0	0				
18							*	*	*	*				
19							*	*	*	*				
20							*	*	*	*	*			
21							*	*	*	*	*			
22							*	*	*	*	*			
23								*	*	*	*			
24								*	*	*	*			
25			*	*	*	*	*	*	*	*	*			
26			*	*	*	*	*	*	*	*	*			
27			*	*	*	*	*	*	*	*	*	*	*	
28			*	*	*	*	*	*	*	*	*	*	*	
29						*	*	*	*	*	*	*	*	
30						*	*	*	*	*	*	*	*	
31							*	*	*	*	*	*	*	
32							*	*	*	*	*			
33							*	*	*	*	*			

Figure 41. Dredging depths in the 5- to 10-ft sediment layer, option C

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2									*	*				
3									*	*				
4									*	*	*			
5									*	*	0	0		
6										6	6	6	6	*
7										6	6	6	*	*
8									*	6	6	6		
9								*	6	6	6	6	*	
10								*	6	6	6	6	*	
11								6	6	6	6			
12							6	6	6	6	*			
13						*	6	6	6	6	*			
14						*	6	6	6	6				
15							*	6	6	6				
16							*	6	6	6				
17							*	0	0	0				
18							*	*	*	*				
19							*	*	*	*				
20							*	*	*	*	*			
21							*	*	*	*	*			
22							*	*	*	*	*			
23								*	*	*	*			
24								*	*	*	*			
25			*	*	*	*	*	*	*	*	*			
26			*	*	*	*	*	*	*	*	*			
27			*	*	*	*	*	*	*	*	*	*	*	
28			*	*	*	*	*	*	*	*	*	*	*	
29						*	*	*	*	*	*	*	*	
30						*	*	*	*	*	*	*	*	
31							*	*	*	*	*	*	*	
32							*	*	*	*	*			
33							*	*	*	*	*			

Figure 42. Dredging depths in the sediment layer below 10 ft, option C

APPENDIX A: TOPOGRAPHIC AND HYDROGRAPHIC SURVEY MAPS

INDEX

Drawing No.	Sheet No.	Title
B-339	1 of 1	Topographic survey: Vicinity of potential disposal sites
B-339	1 of 9	Topographic survey: Potential disposal sites 10 and 10A
B-339	2 of 9	Topographic survey: Potential disposal sites 8 and 9
NB-339	3 of 9	Topographic survey: Potential disposal sites 7 and 12
NB-339	4 of 9	Topographic survey: Potential disposal sites 5, 6, and 11
NB-339	5 of 9	Topographic survey: Potential disposal sites 1A and 3
NB-339	6 of 9	Topographic survey: Potential disposal sites 1, 1A, and 3
NB-339	7 of 9	Topographic survey: Potential disposal sites 1B and 2
NB-339	8 of 9	Topographic survey: Potential disposal site 1B
NB-339	9 of 9	Topographic survey: northern limit
NB-343	1 of 2	Hydrographic survey: Upper Acushnet River Estuary
NB-343	2 of 2	Hydrographic survey: Upper Acushnet River Estuary
NB-345	1 of 4	Proposed disposal sites 1, 1A, and 3
NB-345	2 of 4	Proposed disposal site 1B
NB-345	3 of 4	Proposed disposal site 6
NB-345	4 of 4	Proposed disposal site 12

CORPS OF ENGINEERS — U. S. ARMY

NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY
TOPOGRAPHIC SURVEY
NB-339

GENERAL NOTES:

1. ELEVATIONS ARE EXPRESSED IN FEET AND TENTHS AND ARE REFERRED TO THE PLANE OF MEAN LOW WATER.

2. THE CONTOURS SHOWN HERE REFER TO THE CONDITIONS AT THE TIME THE SURVEY WAS PERFORMED. THE CONTOUR INTERVAL IS 2 FEET.

3. THE SURVEY WAS CONDUCTED DURING THE MONTH(S) OF:

   DATES

   AERIAL PHOTOGRAPHY FLOWN - APRIL 15, 1987
   LAND CONTROL - JUNE & JULY 1987 FIELDBOOKS: [illegible]

4. BENCH MARK DATA:

   BENCH MARK 2 (1931) IS A STANDARD DISK, STAMPED "NO 2 1931", SET IN NORTHEAST CORNER OF GRANITE BLOCK UNDER SECOND GRANITE COLUMN NORTH OF CENTER DOORS OF PLEASANT STREET ENTRANCE TO POST OFFICE AT INTERSECTION OF MIDDLE AND PLEASANT STREETS. IT IS LEVEL WITH MAIN FLOOR OF BUILDING, 4½ FEET ABOVE LAWN AND 56 FEET SOUTH OF NORTHEAST CORNER OF BUILDING. ELEVATION: 75.[illegible] FEET ABOVE MEAN LOW WATER.

   BENCH MARK 12 (1931) IS A STANDARD DISK, STAMPED "NO 12 1931", SET IN GRANITE FOUNDATION OF BRICK MILL BUILDING OF NEW BEDFORD RAYON COMPANY, [illegible] RIVERSIDE AVENUE. IT IS 1½ FEET ABOVE LEVEL OF SIDEWALK AND 5½ FEET NORTH OF ENTRANCE TO MAIN OFFICE ON RIVERSIDE AVENUE. ELEVATION: 14.[illegible] FEET ABOVE MEAN LOW WATER.

   90AG IS A SMALL DRILL HOLE, IN THE TOP OF A LEDGE OUTCROP, ABOUT 1 MILE SOUTH OF ACUSHNET TOWN HALL, LOCATED AT THE SOUTHWEST CORNER OF LAWSON AVENUE AND MAIN STREET; 63 FEET WEST OF THE CENTER LINE OF SOUTH MAIN STREET; [illegible] FEET SOUTH OF THE CENTER LINE OF LAWSON AVENUE AND 165.7 FEET NORTHWEST OF THE NORTHWEST CORNER OF THE RESIDENCE OF F. GAUCHER. ELEVATION: 52.32 FEET ABOVE MEAN LOW WATER.

   90AS IS A STANDARD DISK, STAMPED "90AS-23.23", SET IN A CONCRETE MONUMENT, THE TOP OF WHICH IS 2" BELOW THE SIDEWALK, ABOUT 2 MILES NORTH OF FAIRHAVEN CENTER ON SOUTHWEST SIDE OF MAIN STREET AT ITS JUNCTION WITH NEWBURY STREET; [illegible] SOUTH EAST OF CENTER LINE OF NEWBURY STREET; 24' SOUTHWEST OF CENTER LINE OF MAIN STREET; 57.3' SOUTHWEST OF HYDRANT ON EAST SIDE OF MAIN STREET; 12.8' SOUTHEAST OF THE SOUTH-EAST CORNER OF HENRI ROCISBART'S RESIDENCE, [illegible] MAIN STREET; AND 42.8' SOUTHEAST OF POST MARKING THE NORTH EAST CORNER OF ROCISBART'S PROPERTY. ELEVATION: 2[illegible] FEET ABOVE MEAN LOW WATER.

   91AS IS A STANDARD DISK, STAMPED "91AS-15.61", SET IN A CONCRETE MONUMENT, FLUSH WITH SIDEWALK, IN THE EASTERN PART OF NEW BEDFORD, ON THE SOUTHWEST CORNER OF THE INTERSECTION OF COFFIN AND BELLEVILLE AVENUES; [illegible] FEET SOUTHWEST OF SOUTHWEST CORNER OF DRUG STORE; [illegible] FEET SOUTH OF SOUTHEAST CORNER OF HOUSE, [illegible] BELLEVILLE AVENUE; 18.2 FEET NORTH OF THE NORTHEAST CORNER OF HOUSE, [illegible] COFFIN AVENUE; 32 FEET WEST OF THE CENTERLINE OF BELLEVILLE AVENUE; 16 FEET SOUTH OF CENTERLINE OF COFFIN AVENUE AND 3 FEET EAST OF CENTER OF HYDRANT. ELEVATION: 15.[illegible] FEET ABOVE MEAN LOW WATER.

   91BE IS A STANDARD DISK, STAMPED "91BE-28.22", SET IN A CONCRETE MONUMENT, THE TOP OF WHICH IS FLUSH WITH THE GROUND, ABOUT ½ MILE SOUTH OF NEW BEDFORD CENTER, ON THE NORTHWEST CORNER OF SOUTH SIXTH STREET AND WING STREET; 8.9 FEET SOUTHEAST OF SOUTHEAST CORNER OF HOUSE, [illegible] WING STREET; 30.2 FEET SOUTHWEST OF SOUTHWEST CORNER OF HOUSE, [illegible] SOUTH SIXTH STREET; 7.[illegible] FEET WEST OF CURB; [illegible] FEET NORTHWEST OF THE NORTHWEST CORNER OF HOUSE, [illegible] SOUTH SIXTH STREET; 22.[illegible] FEET NORTH OF 1.7-FOOT MAPLE ON WEST SIDE OF SOUTH SIXTH STREET AND 6 FEET NORTH OF LIGHT POLE. ELEVATION: 27.[illegible] FEET ABOVE MEAN LOW WATER.

   91D IS A STANDARD DISK, STAMPED "91D-17.[illegible]", SET IN A CONCRETE MONUMENT, FLUSH WITH THE GROUND, ON TARKLIN HILL ROAD; 1[illegible] FEET SOUTHEAST OF THE INTERSECTION OF BELLEVILLE AVENUE; 171 FEET EAST OF HYDRANT; [illegible] FEET SOUTHEAST OF THE SOUTH-EAST CORNER OF GAS STATION; [illegible] FEET NORTHEAST OF THE NORTHEAST CORNER OF THE CASTAWAYS RESTAURANT AND 18 FEET SOUTH OF CENTER LINE OF ROAD. ELEVATION: 1[illegible].37 FEET ABOVE MEAN LOW WATER.

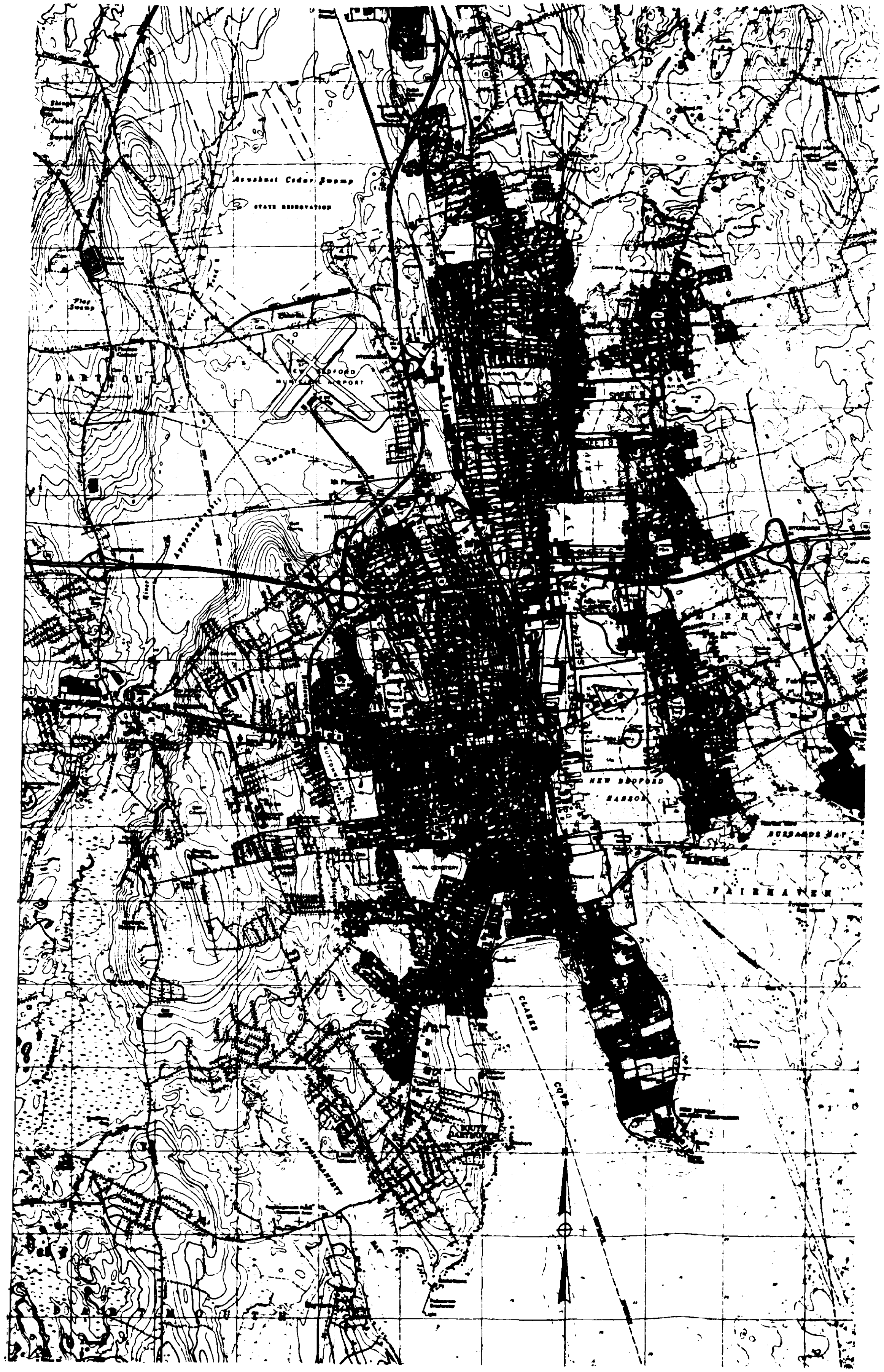
   BENCH MARK [illegible] IS A MARK IN THE TOP OF THE REAR SIGHT CAST ON THE REAR OF BARREL OF WORLD WAR I CANNON. THE MARK IS LOCATED IN THE CENTER OF VILLAGE OF NO. FAIRHAVEN AT THE JUNCTION ACUSHNET, HOWLAND AND MAIN STREET. THE MARK IS SPECIFICALLY LOCATED IN THE SOUTH END OF THE GREEN SEPARATING THE ABOVE STREETS. IT IS 32.9' EAST OF THE SOUTHWEST JUNCTION OF BLACK TOP WALK AND INSIDE OF GRANITE CURB, 29.9' WEST OF THE S.E. JUNCTION OF BLACK TOP WALK AND INSIDE OF GRANITE CURB, AND 31.9' SOUTH OF THE WOODEN FLAG POLE. ELEVATION: [illegible] FEET ABOVE MEAN LOW WATER.

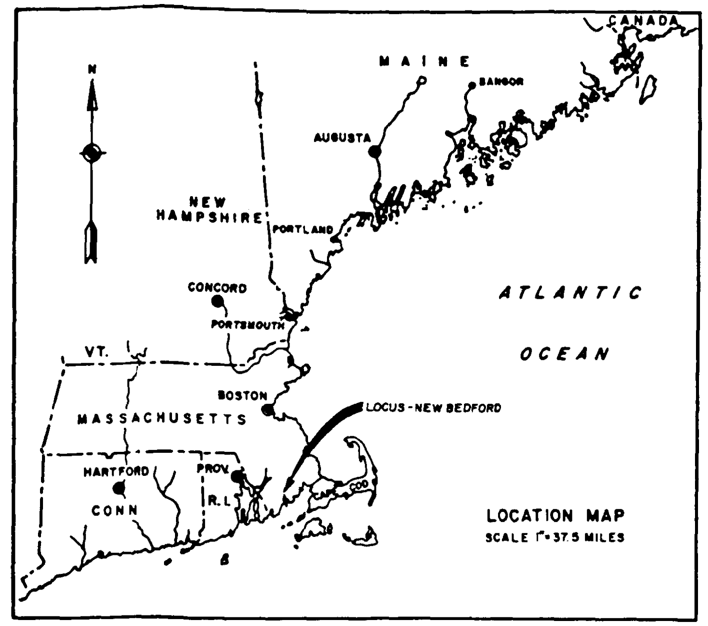
   BENCH MARK [illegible] IS A BENCH MARK DISC, STAMPED "[illegible]", SET FLUSH IN THE TIP OF THE NORTHWEST ENDPOST OF THE MAIN STREET BRIDGE OVER ROUTE I-195. ELEVATION: 56.[illegible] FEET ABOVE MEAN LOW WATER.

   BENCH MARK [illegible] IS A BENCH MARK DISC, STAMPED "[illegible]", SET FLUSH IN THE TOP OF THE NORTHEAST ENDPOST OF THE ROUTE I-195 WESTBOUND BRIDGE OVER RIVER AVENUE. ELEVATION: 3[illegible] FEET ABOVE MEAN LOW WATER.

   BENCH MARK [illegible] THE STATION IS AN ESCUTEON PIN IN LEAD, SET IN THE TOP OF A GRANITE MASS, HIGHWAY BOUND WHICH IS LOCATED ON THE EAST SIDE OF BELLEVILLE AVENUE AT ITS INTERSECTION WITH KENYON STREET, AT THE SOUTH END OF A CHAIN LINK FENCE AT THE BACK EDGE OF THE STONEDUST SIDEWALK, ON THE EAST SIDE OF BELLEVILLE AVENUE. IT IS: 112' SOUTH OF THE SOUTH SIDE OF THE ROUTE I-195 BRIDGE OVER BELLEVILLE AVENUE; 4.9' EAST OF THE FRONT EDGE OF THE CURB; 8.0' SOUTHEAST OF A DRILLHOLE IN THE CURB; 7.5' NORTHEAST OF ANOTHER DRILLHOLE IN THE CURB.

5. COORDINATES ARE BASED ON THE LAMBERT GRID SYSTEM FOR THE COMMONWEALTH OF MASSACHUSETTS.





LOCATION MAP
SCALE 1" = 37.5 MILES

LEGEND

- SWAMP
- MEAN LOW WATER LINE
- CONTOUR LINE
- SPOT ELEVATION
- RIP RAP
- FENCE, BULKHEAD
- PAVED ROADWAY
- GRAVEL ROADWAY
- TRAIL
- TELEPHONE POLE
- RETAINING WALL
- TREE LINE
- GUARD RAIL
- TRIANGULATION SURVEY STATION

INDEX OF POTENTIAL DISPOSAL SITES

SHEET	SITE
1	10 & 10A
2	8 & 9
3	7 & 12
4	5, 6 & 11
5	1A & 3
6	1, 1A & 3
7	1B & 2
8	1B
9	Northern Limit

VALUE ENGINEERING PAYS DIVIDENDS

SAFETY PAYS

GRAPHIC SCALES
1" = 37.5 MI. 25 0 25 50 75 MI.
1" = 2000 FT. 2000' 0 1000' 3000' 5000'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED: PROJECT MANAGER
REVIEWED: CHIEF, COAST. ENG./SUR. SECT.
APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH

NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY
TOPOGRAPHIC SURVEY
VICINITY OF POTENTIAL DISPOSAL SITES

APPROVED: CHIEF, ENGINEERING DIVISION
DATE October 1987

SCALE AS SHOWN | SPEC. NO. DACW 33

DRAWING NUMBER NB-339

SHEET INDEX

CORPS OF ENGINEERS

U. S. ARMY

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SAFETY PAYS

GRAPHIC SCALES

100 0 100 200

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CORPS OF ENGINEERS
WALTHAM, MASS.

NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY
TOPOGRAPHIC SURVEY
POTENTIAL DISPOSAL SITES 10 & 10A

SUBMITTED: PROJECT MANAGER
REVIEWED: CHIEF, COAST. ENG/SUR SECT.
APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH
APPROVED: CHIEF, ENGINEERING DIVISION

DATE OCT 1987

SCALE 1" = 100' SPEC. NO. DACW 33

DRAWING NUMBER NB-339

SHEET 1 OF 9

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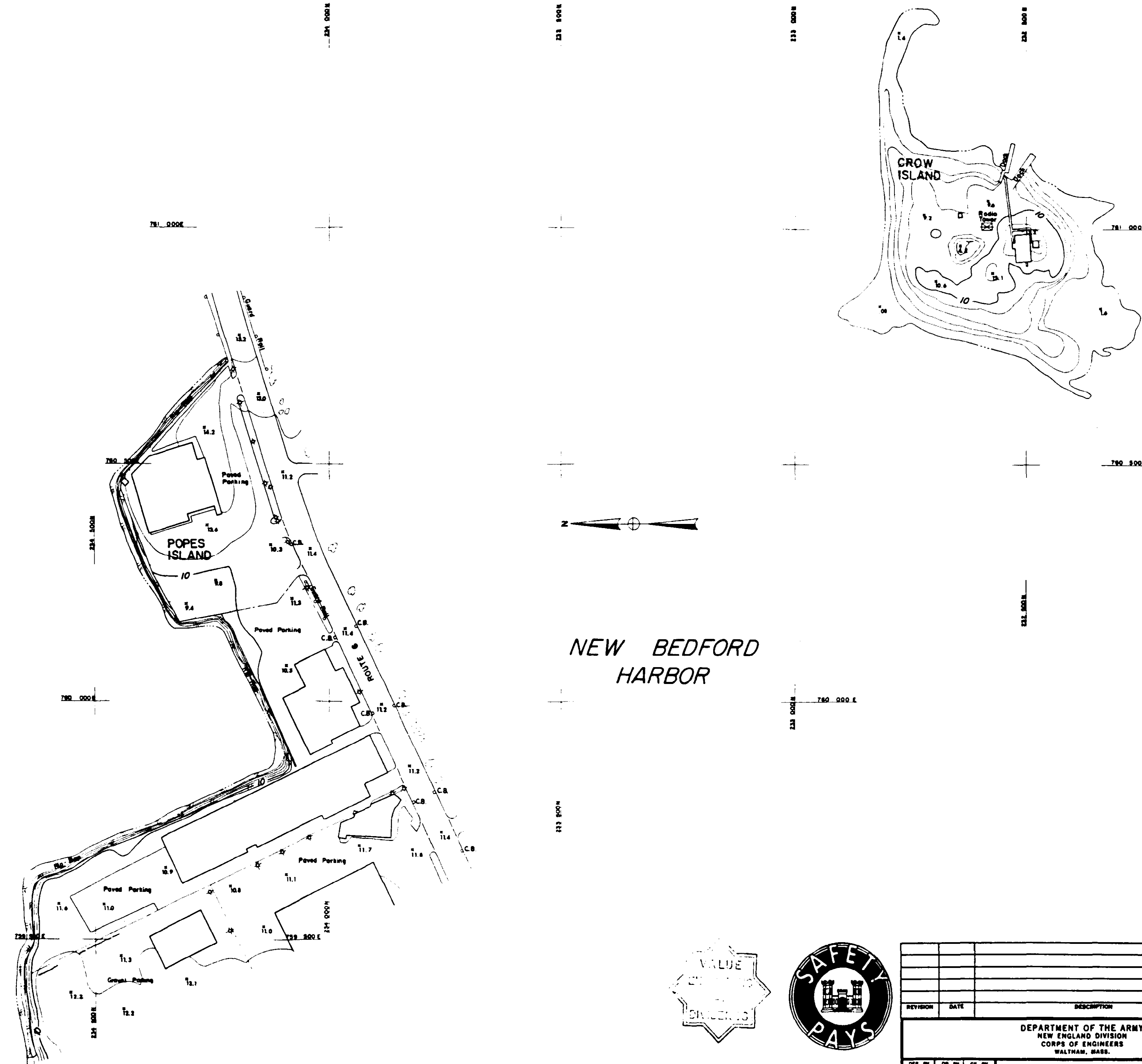

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APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH

NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY

TOPOGRAPHIC SURVEY
POTENTIAL DISPOSAL SITES 8 & 9

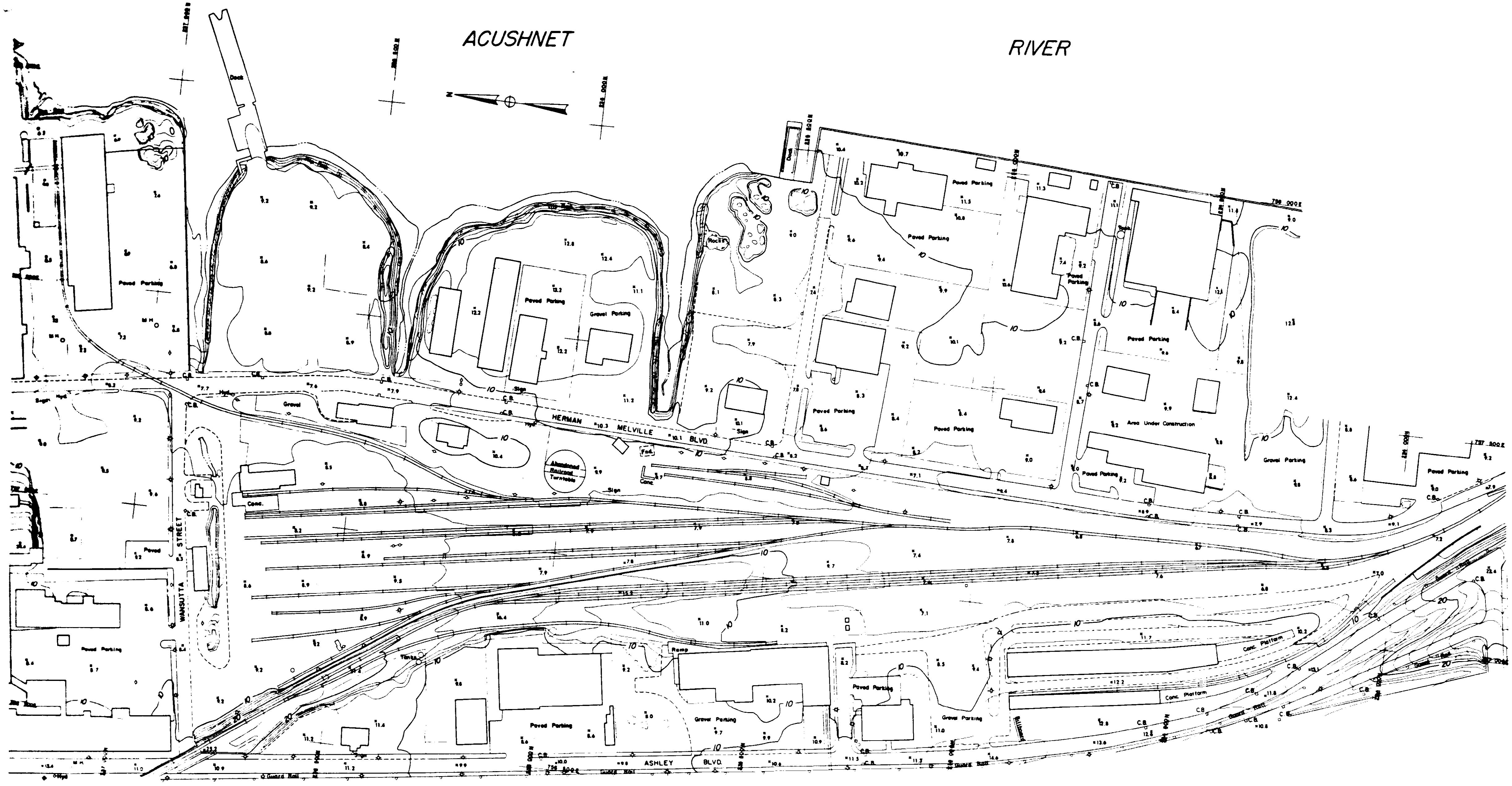
APPROVED: CHIEF, ENGINEERING DIVISION

DATE OCT 1987

SCALE 1" = 100' | SPEC. NO. DACW 33

DRAWING NUMBER NB-339

SHEET 2 OF 9



NOTE: For General Notes and Legend, See Index Sheet.

GRAPHIC SCALES

100 0 100 200

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REVIEWED: CHIEF, COAST. ENG/SUR SECT.
APPROVAL RECOMMENDED: CHIEF DESIGN BRANCH

NEW BEDFORD, MASSACHUSETTS ENGINEERING FEASABILITY STUDY

TOPOGRAPHIC SURVEY POTENTIAL DISPOSAL SITES 7 & 12

APPROVED CHIEF, ENGINEERING DIVISION

DATE OCT 1987

SCALE 1"=100' | SPEC. NO. DACW 33

DRAWING NUMBER NB-339

SHEET 3 OF 9

U. S. ARMY CORPS OF ENGINEERS

VALUE ENGINEERING PAYS DIVIDENDS

SAFETY PAYS

GRAPHIC SCALES

100 0 100 200

NOTE: For General Notes and Legend, See Index Sheet.

REVISION	DATE	DESCRIPTION	BY

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CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY PBL

SUBMITTED: PROJECT MANAGER

REVIEWED: CHIEF, COAST. ENG/SAR SECT.

APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH

NEW BEDFORD, MASSACHUSETTS ENGINEERING FEASABILITY STUDY

TOPOGRAPHIC SURVEY

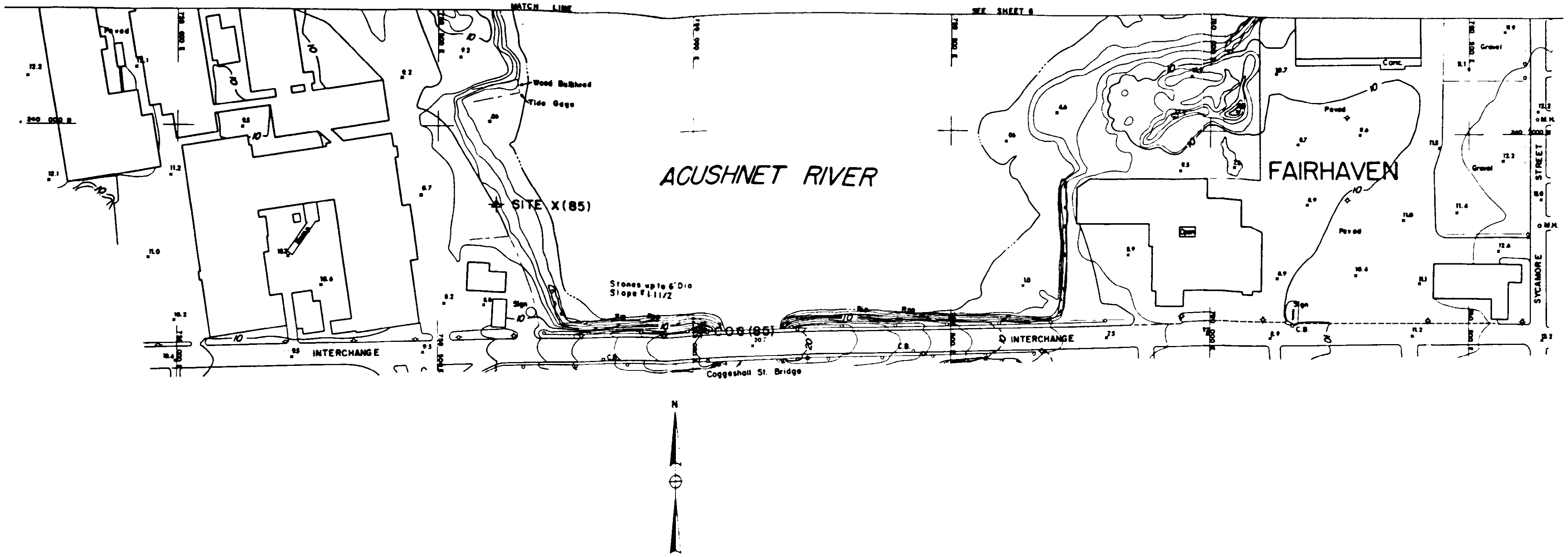
POTENTIAL DISPOSAL SITES 5, 6, & 11

APPROVED CHIEF, ENGINEERING DIVISION DATE OCT 1987

SCALE 1" = 100' SPEC. NO. DACW 33

DRAWING NUMBER NB-339

SHEET 4 OF 9



NOTE: For General Notes and Legend, See Index Sheet.
(I),(A) Identifies Location of Grid block.

VALUE ENGINEERING PAYS DIVIDENDS

SAFETY PAYS

GRAPHIC SCALES
1" = 100'   100' 0 100' 200'

REVISION	DATE	DESCRIPTION	BY

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NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

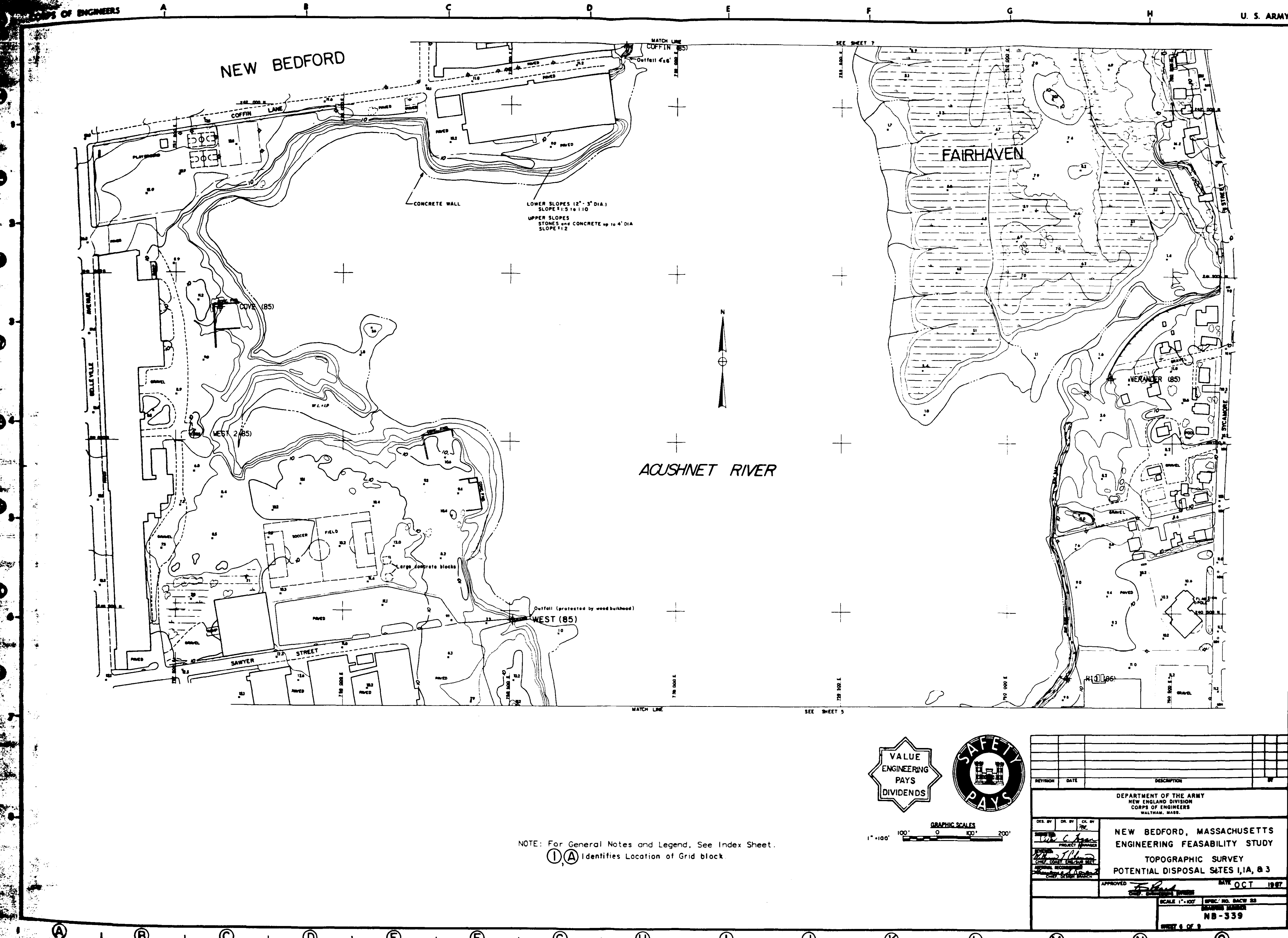
DES. BY | DR. BY | CK. BY PER

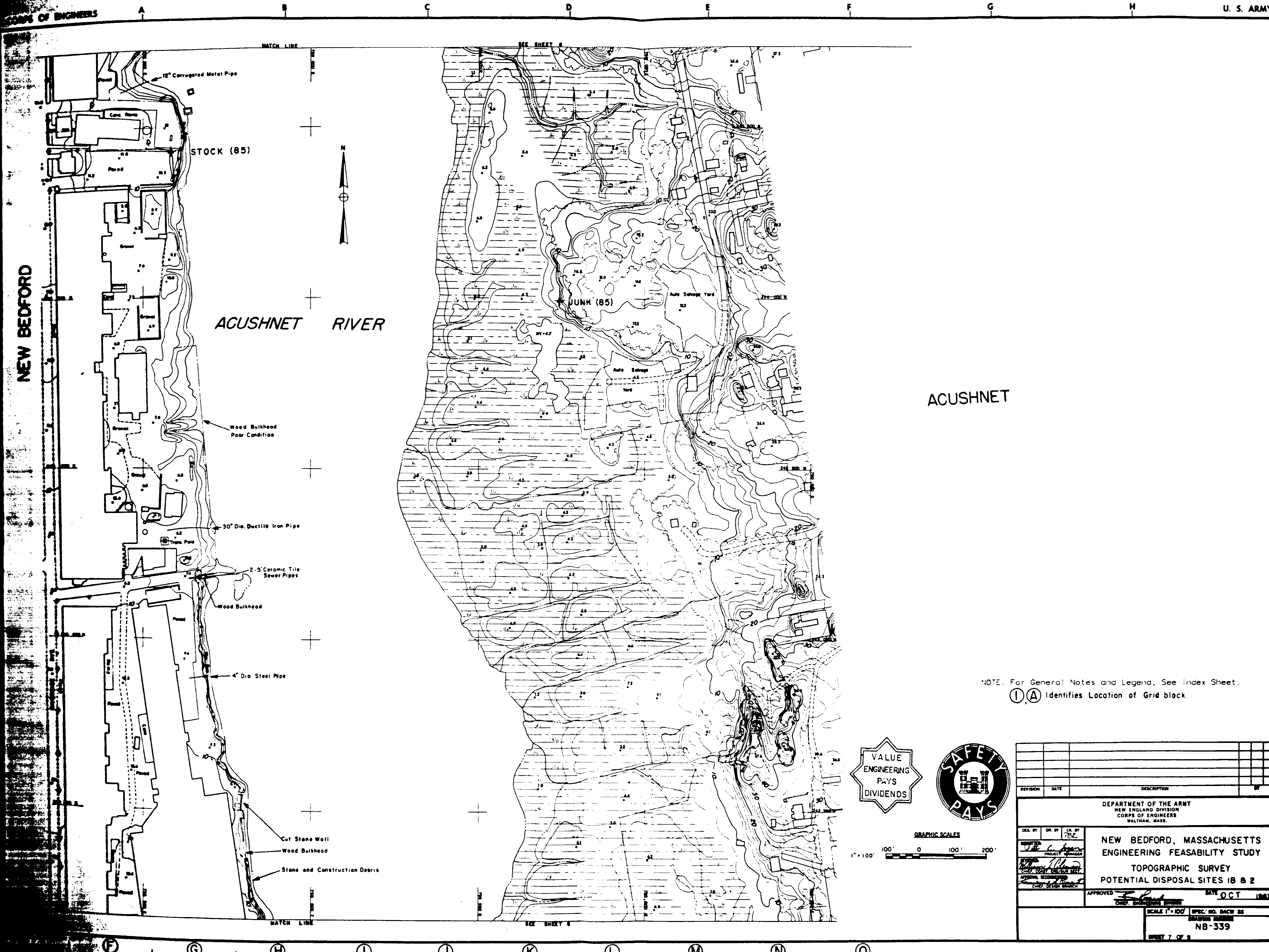
SUBMITTED: PROJECT MANAGER
REVIEWED: CHIEF, COAST. ENG/SUR SECT.
APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH

NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY
TOPOGRAPHIC SURVEY
POTENTIAL DISPOSAL SITES IA & 3

APPROVED CHIEF, ENGINEERING DIVISION   DATE OCT 1987

SCALE 1" = 100'   SPEC. NO. DACW 33
DRAWING NUMBER
NB-339
SHEET 5 OF 9


CORPS OF ENGINEERS
U. S. ARMY
NEW BEDFORD
FAIRHAVEN
ACUSHNET RIVER
COFFIN LANE
SAWYER STREET
BELLEVILLE AVENUE
SYCAMORE STREET
MATCH LINE SEE SHEET 7
MATCH LINE SEE SHEET 5
COFFIN (85)
COVE (85)
WEST 2 (85)
WEST (85)
VERANDER (85)
Outfall 4'x6'
Outfall (protected by wood bulkhead)
CONCRETE WALL
LOWER SLOPES (2" - 3" DIA.) SLOPE ± 1:5 to 1:10
UPPER SLOPES STONES and CONCRETE up to 4' DIA. SLOPE ± 1:2
PLAYGROUND
SOCCER FIELD
Large concrete blocks
PAVED
GRAVEL
N
NOTE: For General Notes and Legend, See Index Sheet.
Ⓘ,Ⓐ Identifies Location of Grid block.
VALUE ENGINEERING PAYS DIVIDENDS
SAFETY PAYS
GRAPHIC SCALES
1" = 100'
100' 0 100' 200'
REVISION
DATE
DESCRIPTION
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY
DR. BY
CK. BY
SUBMITTED
PROJECT MANAGER
REVIEWED
CHIEF, COAST. ENG./SUR. SECT.
APPROVAL RECOMMENDED
CHIEF, DESIGN BRANCH
NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY
TOPOGRAPHIC SURVEY
POTENTIAL DISPOSAL SITES I, IA, & 3
APPROVED
CHIEF, ENGINEERING DIVISION
DATE OCT 1987
SCALE 1" = 100'
SPEC. NO. DACW 33
DRAWING NUMBER
NB-339
SHEET 6 OF 9



NOTE: For General Notes and Legend, See Index Sheet.
(1),(A) Identifies Location of Grid block.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY TBC

SUBMITTED: PROJECT MANAGER
REVIEWED: CHIEF, COAST. ENG./SUR. SECT.
APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH

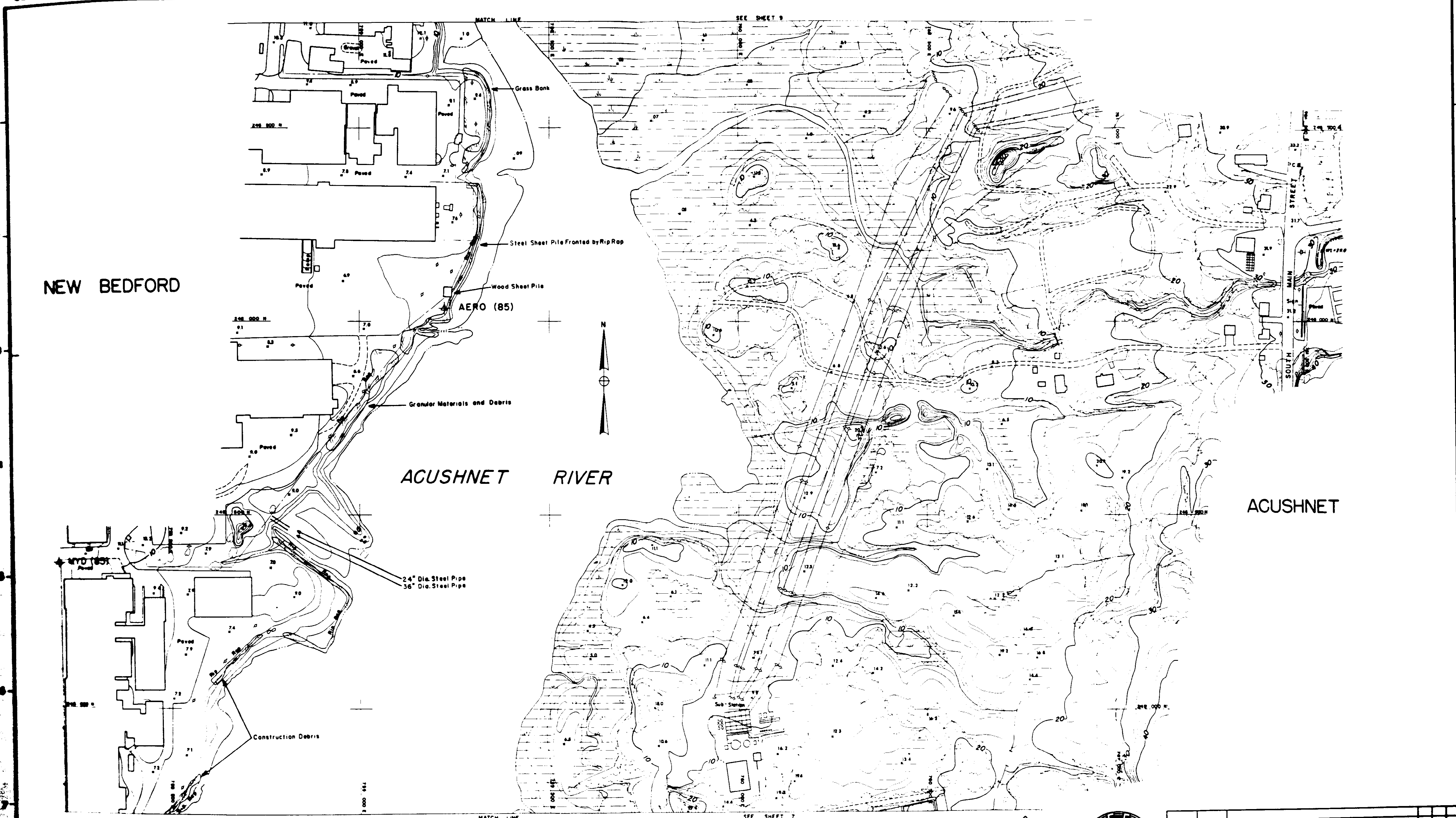
NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY
TOPOGRAPHIC SURVEY
POTENTIAL DISPOSAL SITES 1B & 2

APPROVED: CHIEF, ENGINEERING DIVISION
DATE OCT 1987

SCALE 1" = 100' | SPEC. NO. DACW 33

DRAWING NUMBER
NB-339

SHEET 7 OF 9



VALUE ENGINEERING PAYS DIVIDENDS

SAFETY PAYS

NOTE: For General Notes and Legend, See Index Sheet.
(I)(A) Identifies Location of Grid block.

GRAPHIC SCALES
1"=100' 100' 0 100' 200'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY · DR. BY · CK. BY

SUBMITTED: PROJECT MANAGER

REVIEWED: CHIEF COAST ENG/SUR SECT.

APPROVAL RECOMMENDED: CHIEF DESIGN BRANCH

APPROVED: CHIEF, ENGINEERING DIVISION

NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY

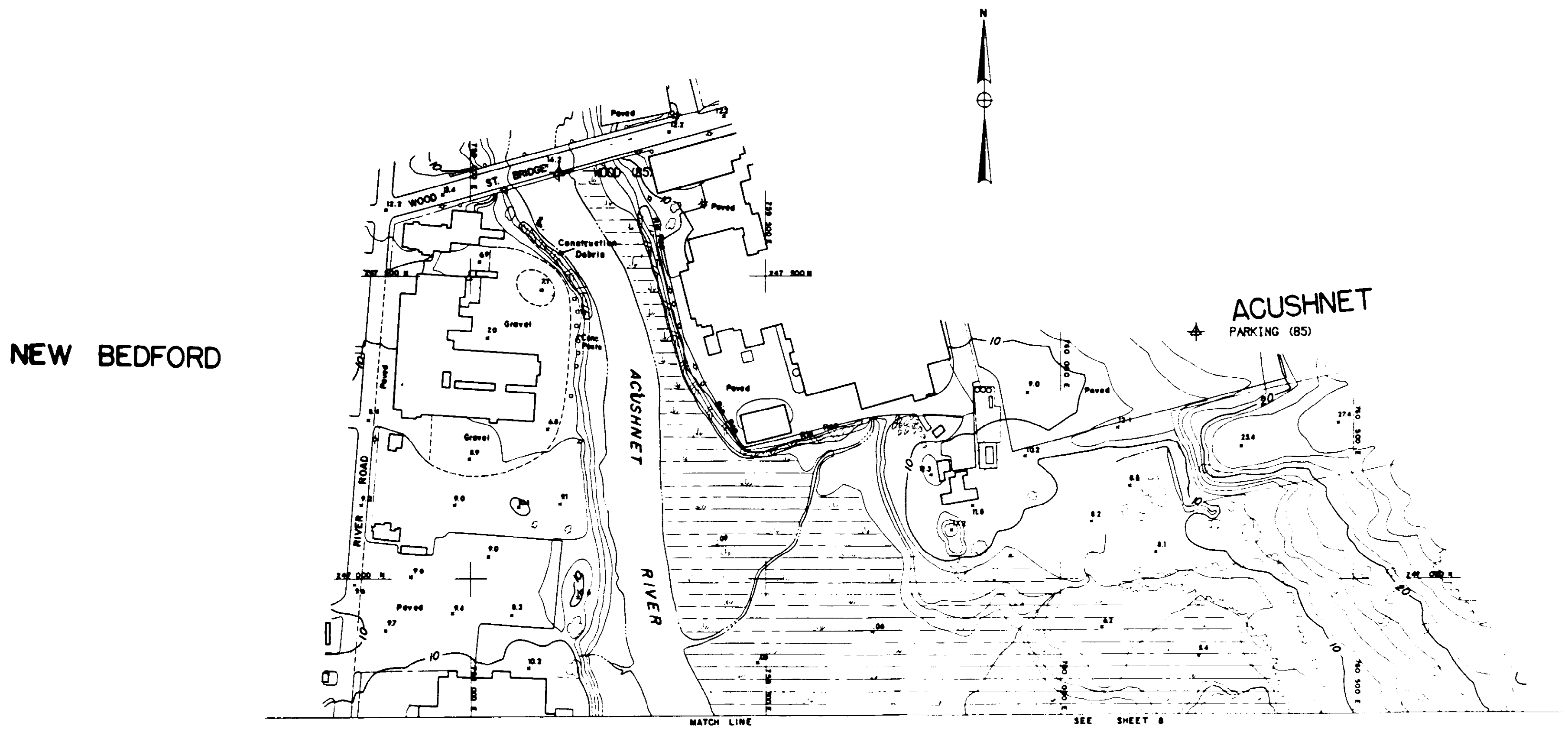
TOPOGRAPHIC SURVEY
POTENTIAL DISPOSAL SITE 1B

DATE OCT 1987

SCALE 1"=100' · SPEC. NO. DACW 33

DRAWING NUMBER NB-339

SHEET 8 OF 9



VALUE ENGINEERING PAYS DIVIDENDS

SAFETY PAYS

GRAPHIC SCALES

1" = 100' 100' 0' 100' 200'

NOTE: For General Notes and Legend, See Index Sheet.
(I),(A) Identifies Location of Grid block.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED: PROJECT MANAGER

REVIEWED: CHIEF, COAST. ENG/SUR SECT.

APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH

NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY

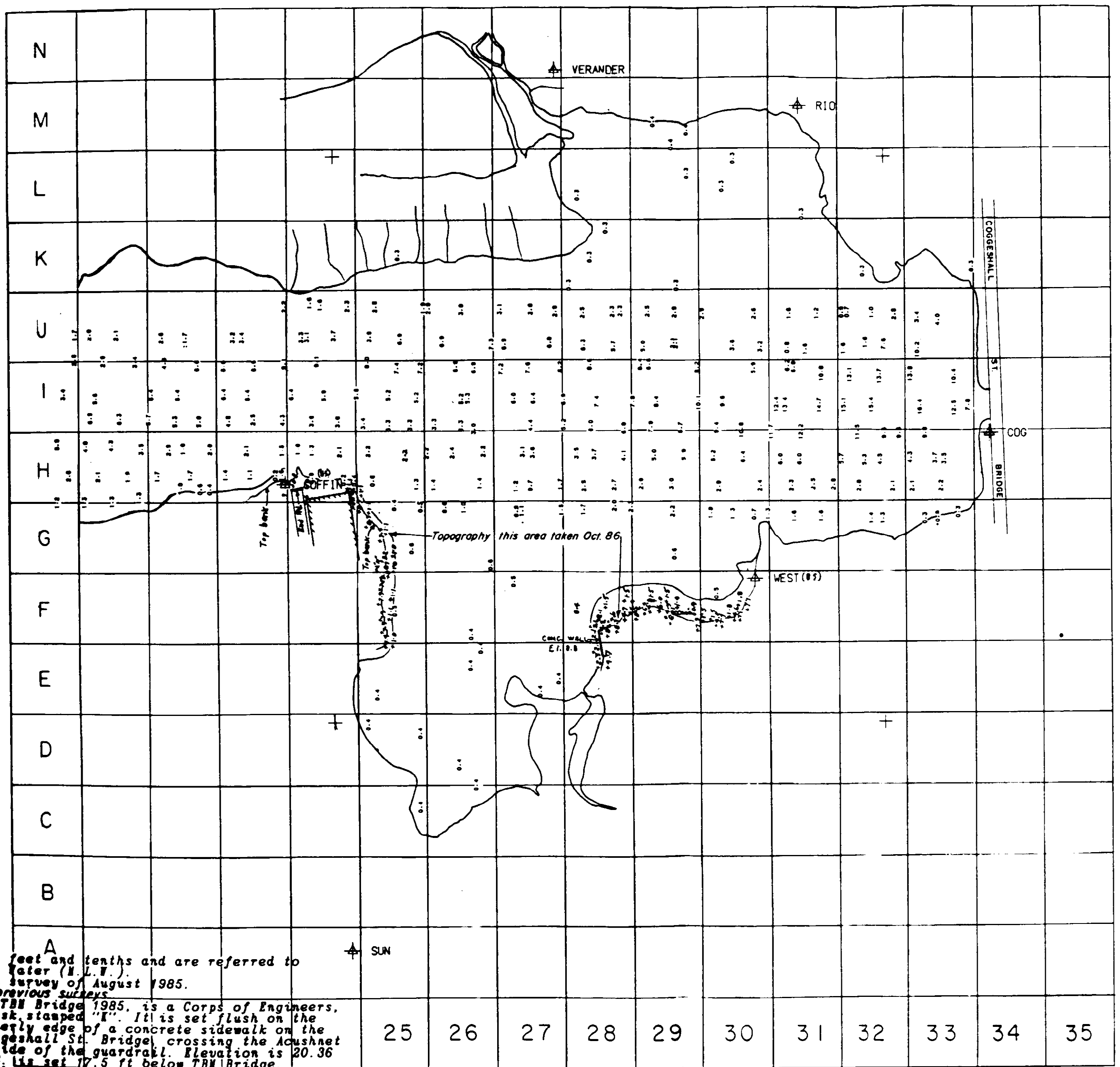
TOPOGRAPHIC SURVEY
NORTHERN LIMIT

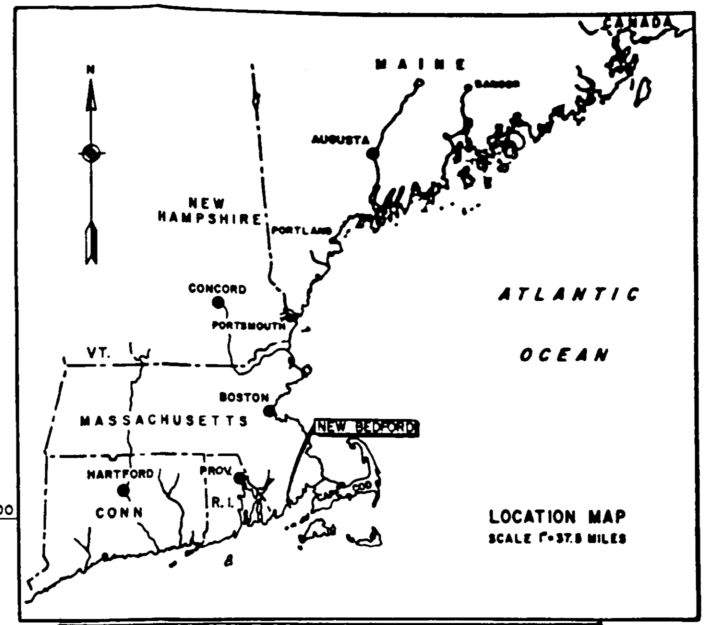
APPROVED

DATE OCT 1987

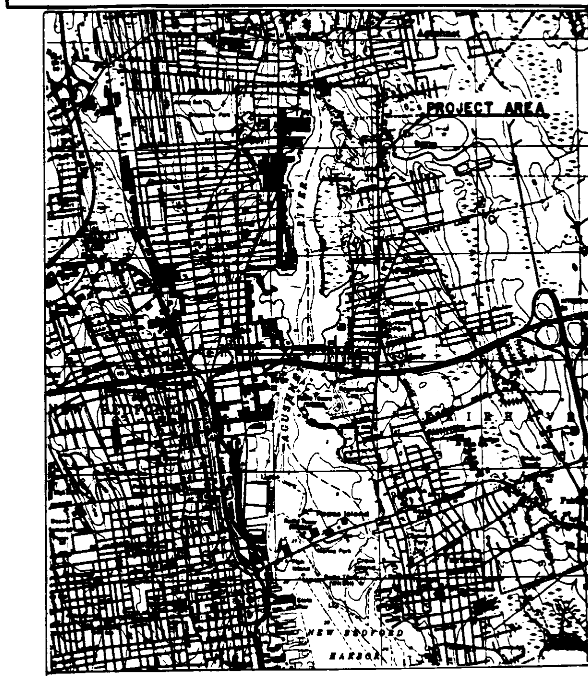
SCALE 1" = 100'

NB-339





E 760000



VICINITY MAP

NOT TO SCALE

E758000

...ERAL NOTES:

...ndings are in feet and tenths and are referred to
... of Mean Low Water (M.L.W.).
...ography from survey of August 1985.
...ography from previous surveys
... Mark Data: TBM Bridge 1985, is a Corps of Engineers,
... standard disk, stamped "K". It is set flush on the
... most northerly edge of a concrete sidewalk on the
... of the Coggeshall St. Bridge crossing the Acushnet
... on the outside of the guardrail. Elevation is 20.36
... M.L.W. T.C. is set 17.5 ft below TBM Bridge.
...dinates are based on the Lambert Grid System for
... of Massachusetts.
... sounding information depicted on these maps
... the SHOALEST soundings of those obtained from
...ic surveys conducted during August 1985.
...ormation should NOT be used to determine volumes."
... information depicted on these maps represents
... of surveys made on the dates indicated
... be considered as indicating the general
... existing at that time."
...: 2309 & 2967.
...ounder Rolls: 85-64, 65, 66, 67, 63

GRAPHIC SCALES

1"=37.5MI. 25 0 25 50 75MI.

1"=200FT. 200' 0 200' 400'

SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY
T.E.R.	E.J.K.	

SUBMITTED: PROJECT MANAGER

REVIEWED: CHIEF, COAST. ENG/SUR SECT.

APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH

PROJECT NO. 110

NEW BEDFORD, MA
ENGINEERING FEASIBILITY STUDY
HYDROGRAPHIC SURVEY
UPPER ACHUSNET RIVER ESTUARY

APPROVED: CHIEF, ENGINEERING DIVISION

DATE APRIL 1988

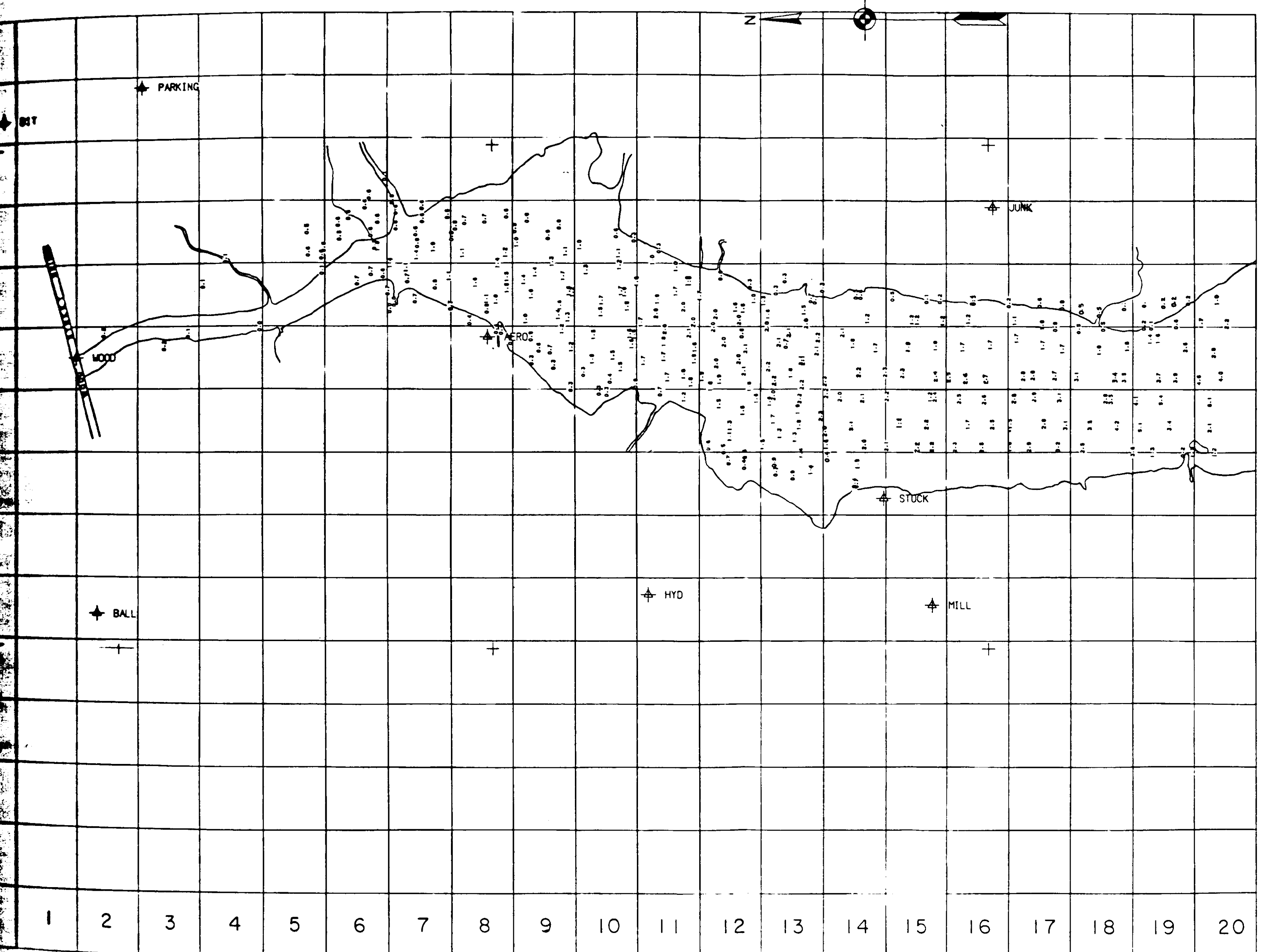
SCALE 1"= 200 SPEC. NO. DACW 33

NB-343

SHEET 1 OF 2

SEE NOAA CHART NO. 13230

U. S. ARMY



GRAPHIC SCALE

1"=200FT. 200' 0 200' 400'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY T.E.R. | DR. BY E.J.K. | CK. BY

SUBMITTED: PB Ruthroll — PROJECT MANAGER

REVIEWED: William Coleman — CHIEF, COAST ENG/SUR SECT

APPROVAL RECOMMENDED: — CHIEF, DESIGN BRANCH

NEW BEDFORD, MA
ENGINEERING FEASIBILITY STUDY
HYDROGRAPHIC SURVEY
UPPER ACHUSNET RIVER ESTUARY

PROJECT NO. 110

APPROVED — CHIEF, ENGINEERING DIVISION

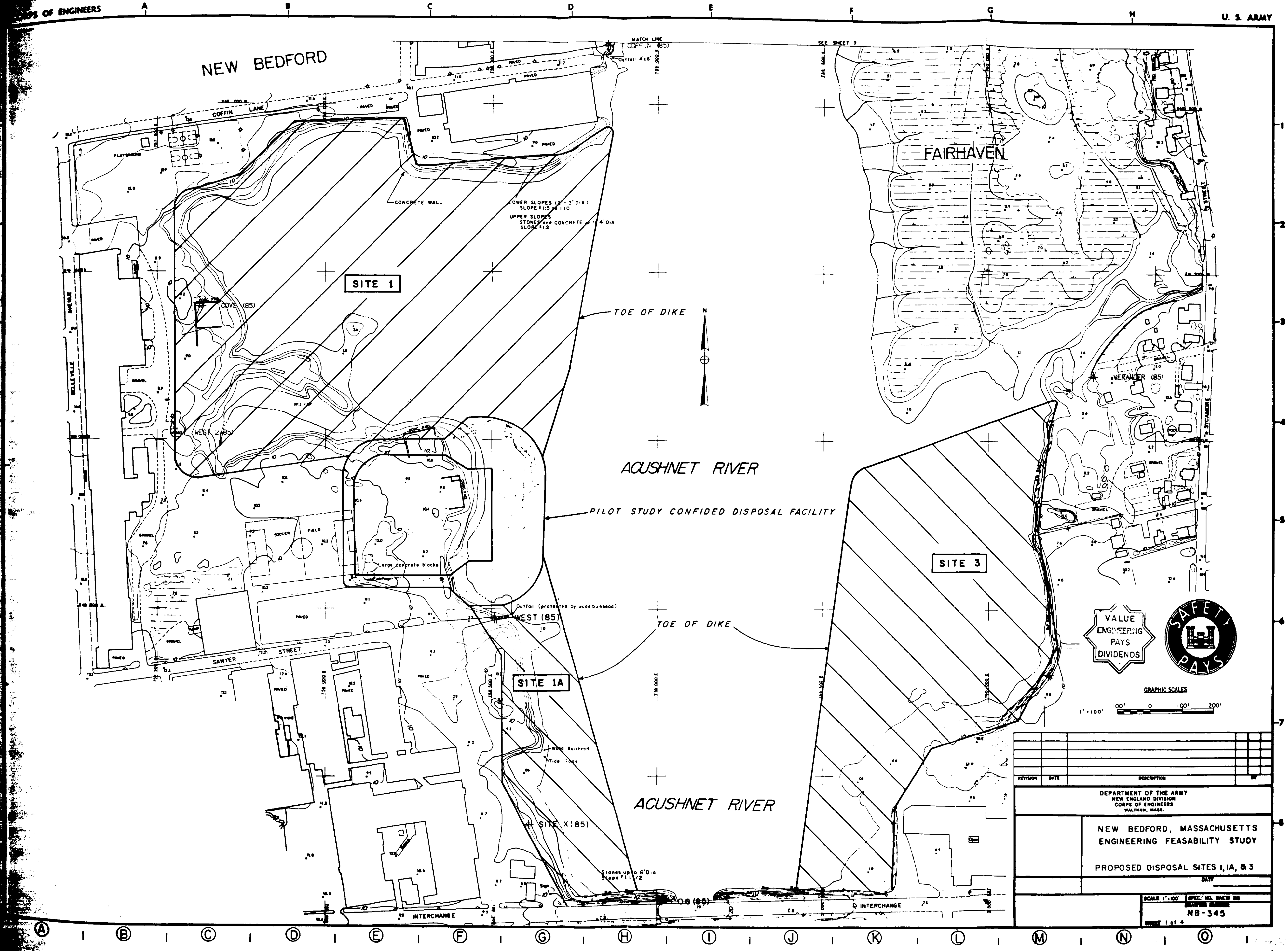
DATE APRIL 1988

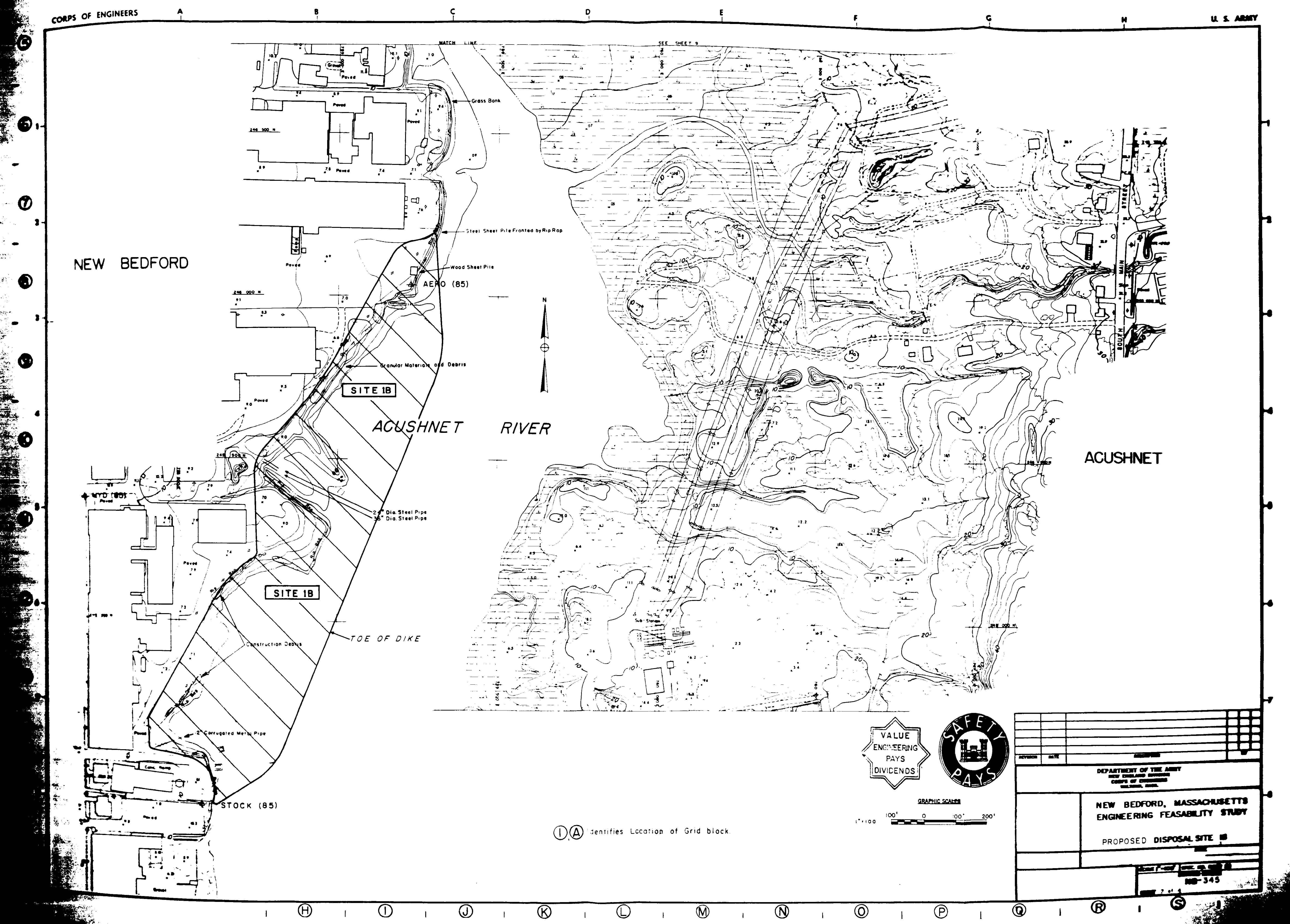
SCALE 1"= 200 | SPEC. NO. DACW 33

DRAWING NUMBER NB-343

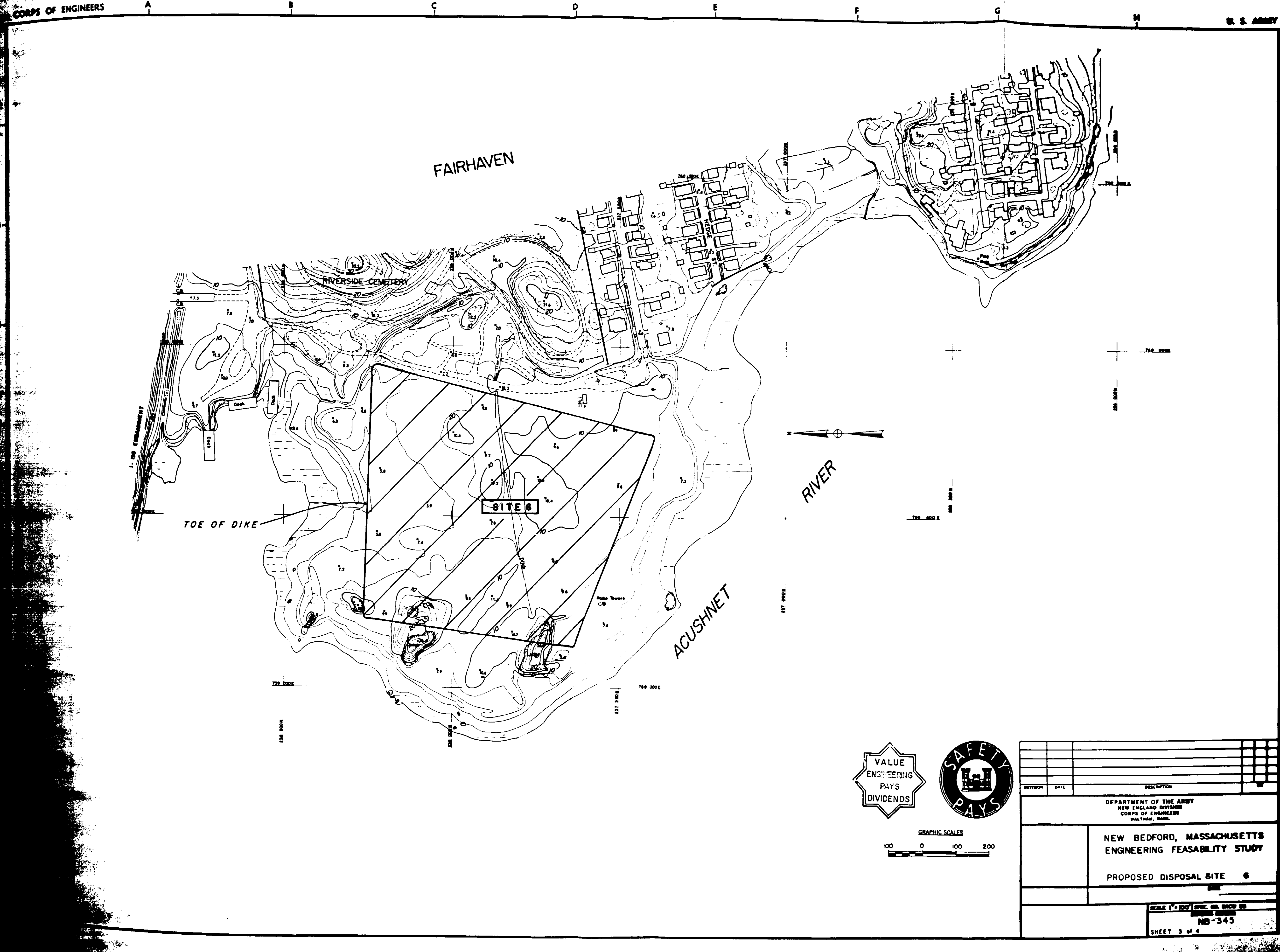
SHEET 2 OF 2

SEE NOAA CHART NO. 13230


CORPS OF ENGINEERS
U. S. ARMY
NEW BEDFORD
FAIRHAVEN
COFFIN LANE
MATCH LINE
SEE SHEET 7
CONCRETE WALL
LOWER SLOPES (2'-3' DIA) SLOPE 1:5 to 1:10
UPPER SLOPES STONES and CONCRETE up to 4' DIA SLOPE 1:2
SITE 1
COVE (85)
WEST 2 (85)
TOE OF DIKE
ACUSHNET RIVER
PILOT STUDY CONFIDED DISPOSAL FACILITY
SOCCER FIELD
Large concrete blocks
Outfall (protected by wood bulkhead)
WEST (85)
SAWYER STREET
BELLEVILLE AVENUE
SITE 1A
SITE 3
VERANDER (85)
SYCAMORE STREET
GRAVEL
PAVED
PLAYGROUND
Wood Bulkhead
Tide Gage
SITE X (85)
Stones up to 6' Dia Slope 1:1 1/2
INTERCHANGE
VALUE ENGINEERING PAYS DIVIDENDS
SAFETY PAYS
GRAPHIC SCALES
1" = 100'
100' 0 100' 200'
REVISION
DATE
DESCRIPTION
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY
PROPOSED DISPOSAL SITES 1, 1A, & 3
DATE
SCALE 1" = 100'
NB-345
SHEET 1 of 4



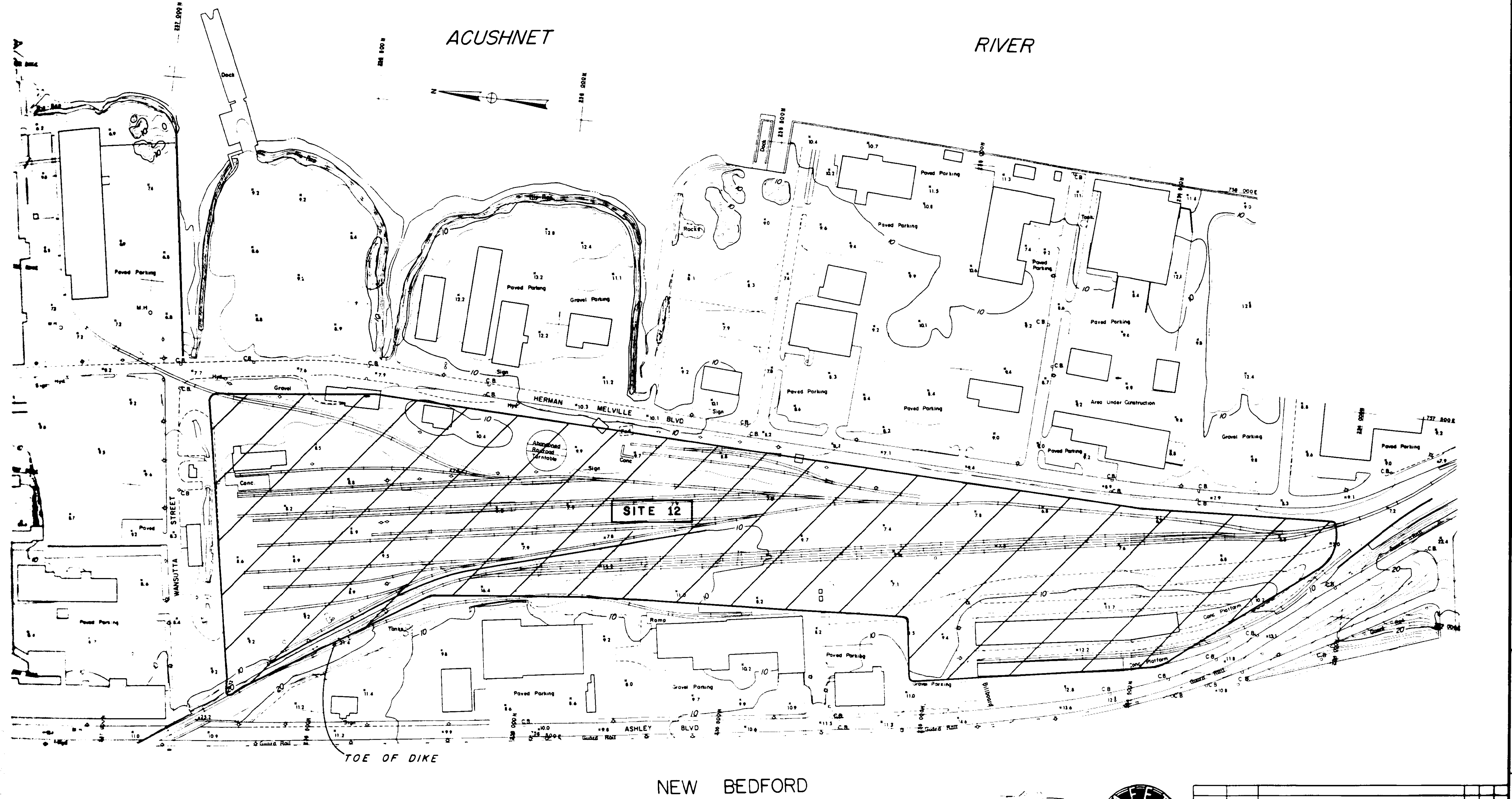
CORPS OF ENGINEERS
U. S. ARMY
MATCH LINE
SEE SHEET 9
NEW BEDFORD
ACUSHNET
ACUSHNET RIVER
SITE 1B
SITE 1B
Grass Bank
Steel Sheet Pile Fronted by Rip Rap
Wood Sheet Pile
AERO (85)
Granular Material and Debris
24" Dia. Steel Pipe
36" Dia. Steel Pipe
TOE OF DIKE
Construction Debris
2" Corrugated Metal Pipe
STOCK (85)
Paved
Sub-Station
MAIN STREET
SOUTH MAIN
N
VALUE ENGINEERING PAYS DIVIDENDS
SAFETY PAYS
GRAPHIC SCALES
1"=100'
100' 0 100' 200'
Ⓘ Ⓐ Identifies Location of Grid block
REVISION
DATE
DEPARTMENT OF THE ARMY
NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY
PROPOSED DISPOSAL SITE 1B
NB-345
7 of 9



CORPS OF ENGINEERS
U. S. ARMY
FAIRHAVEN
RIVERSIDE CEMETERY
HEDGE ST
SITE 6
TOE OF DIKE
ACUSHNET
RIVER
VALUE ENGINEERING PAYS DIVIDENDS
SAFETY PAYS
GRAPHIC SCALES
100 0 100 200
REVISION DATE DESCRIPTION
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY
PROPOSED DISPOSAL SITE 6
SCALE 1"=100'
NB-345
SHEET 3 of 4

CORPS OF ENGINEERS

U. S. ARMY



GRAPHIC SCALES

100 0 100 200

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

NEW BEDFORD, MASSACHUSETTS
ENGINEERING FEASABILITY STUDY

PROPOSED DISPOSAL SITE 12

DATE

SCALE 1"=100' SPEC. NO. DACW 33

DRAWING NUMBER NB-345

SHEET 4 of 4

APPENDIX B: ENGINEERING CHARACTERIZATION OF SEDIMENTS FOR PURPOSES OF DREDGING AND DISPOSAL

Introduction

Background

1. Cleanup dredging alternatives evaluated by the Engineering Feasibi ity Study (EFS) for the New Bedford Superfund Site (Upper Estuary) will require removal of approximately 600,000 cu yd* of highly contaminated material. An engineering characterization of the material to be dredged is need for proper evaluation of dredging equipment and techniques, disposal alterna tives, and contaminant control measures. In addition, for both disposal alternatives under consideration, an additional volume of underlying clean sediment will be dredged for use as a cap to isolate the contaminated materi following disposal. Therefore, an engineering characterization of the under lying clean sediment is also required.

Purpose and scope

2. The purpose of this paper is to present an engineering characteriz tion of sediments to be dredged for the New Bedford Harbor Superfund Site. This paper includes a description of field sampling, laboratory testing, and engineering sediment characterization and a discussion of considerations relating to dredging and disposal.

Grid cell system and sampling and dredging depths

3. A grid cell system (Figure B1) has been developed for the Upper Estuary for purposes of reference and control. This grid cell system was use in referencing sample locations, test results, etc. The grid cell will also provide a convenient means of controlling the dredging and disposal operation For this reason, the grid cells were considered a logical means of grouping and averaging sediment properties within the Upper Estuary. The results of various tests for purposes of sediment characterization are presented as the average value for all samples tested within the respective grid at the respective sediment depth interval.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5 of the main text.

4. Available dredging equipment and techniques will allow controlled removal of layers of sediment approximately 1 ft thick. Most of the contaminants in the Upper Estuary are confined to the upper 1 ft; however, residual contamination due to mixing and resuspension is expected after one dredging pass. For this reason, a second 1-ft pass is anticipated. The upper 2 ft of surficial sediment will be disposed of as contaminated. Underlying clean sediment will be dredged for cap. The dredging depth required for this purpose is assumed not to exceed 10 ft. Sediment characterizations for the upper 2 ft and the underlying sediments are described separately in this engineering characterization.

5. The data in this sediment characterization are grouped and averaged by depth interval for each grid. Sampling has been conducted as a part of the overall EFS on several occasions, and sample types (i.e., push tubes, cores, etc.) and locations varied. Generally, continuous depth samples were not taken; therefore, intervals sampled must be assumed to be representative of a larger depth interval. Also, the sediment depth intervals sampled and/or tested are not consistent for all sample types. All sample types included data for either the 0- to 1-, 1- to 2-, or 0- to 2-ft depth intervals, representative of the contaminated sediments to be dredged. Data for the 2- to 4-ft depth interval sampled are assumed representative of the 2- to 5-ft depth. A majority of data for depths below 5 ft is available at intervals of 5 to 7 ft and 10 to 12 ft or deeper. Data for the 5- to 7-ft interval sampled are considered representative of the 5- to 10-ft depth. Data for the 10- to 12-ft interval sampled are considered representative of any material that would be dredged from depths exceeding 10 ft. A few samples were obtained from the 4- to 6-ft interval. For purposes of this sediment characterization, these samples are considered representative of the 5- to 10-ft depth.

In situ volume to be dredged

6. Prior estimates of the in situ volume of contaminated sediments to be dredged were as high as 1 million cubic yards. These estimates were based on an assumption of 3 ft of surficial sediment to be removed. A refined estimate of the in situ volume to be dredged as contaminated was made based on the sampling conducted as a part of the EFS. Recent sampling has indicated that, with the possible exception of the "hot spot" located adjacent to the Aerovox outfall, PCB contamination is generally limited to the upper 2 ft of sediment. This EFS will consider removal of 2 ft of sediment, although future

determination of action levels may increase or decrease the depth and area to be dredged and disposed of as contaminated material.

7. A revised estimate of in situ volume was based on removal of the upper 2 ft within an assumed dredging boundary defined by the shoreline shown by the New England Division (NED) survey of 13 August 1985. No dredging of the wetland area was assumed in this estimate. The grid cell system as superimposed on this survey was used to define a set of area factors for the grids falling within the shoreline boundaries. Grids lying entirely within the dredging boundaries were given area factors of 1.0. Grids lying partially within the boundaries were assigned area factors based on the portion of the grid surface area lying within the dredging boundary. All area factors were defined to the nearest tenth. A matrix showing area factors for all full and partial grid cells falling within the dredging boundaries is shown as Figure B2. These area factors should be used in all subsequent calculations (volumes, etc.).

8. A total of 176 full or partial grid cells lie within the dredging boundaries. The average area factor for these cells is 0.77. For cell dimensions of 250 by 250 ft, the total surface area to be dredged is approximately 196 acres. Assuming the upper 2 ft is removed, the volume of in situ sediments to be treated as contaminated is approximately 632,000 cu yd.

Field Investigations

Prior sampling

9. A large number of surficial samples have been taken for the Upper Estuary sediments in various studies conducted prior to the EFS. These samples were taken mainly to determine contaminant concentrations, and little physical information was developed. For this reason, sampling and testing conducted prior to the EFS were not considered in this sediment characterization.

Push tube sampling

10. The NED conducted push tube sampling in the Upper Estuary from July to October 1985. The purpose of the sampling was to provide accurate spatial data on sediment characteristics, both physical and chemical. Detailed

discussions of the sampling and handling procedures are described by Condike (1986).*

11. The push tube samples were taken in 2-7/8-in. acrylic tubes using a coring device with a flap/stopper arrangement to provide suction for better sampling recovery. The tubes were pushed by hand and by a steel plate slam-hammer. A total of 168 push tubes were taken, generally one from each grid cell in the Upper Estuary. Average length of the cores was 53 in. Laboratory testing was subsequently done on portions of 31 of these tubes. Locations of these 31 tubes as designated by grid cell are indicated in Figure B3.

Split spoon sampling

12. During October and November 1986, a geotechnical investigation was conducted within the Upper Estuary by an NED contractor. The purpose of the investigation was to determine physical properties of the subsurface materials with depth for use in the design of disposal alternatives. Detailed discussions of the sampling and handling procedures are found in Woodward-Clyde Consultants (1987).

13. A total of 52 borings, probes, or tube samples were taken within the estuary or adjacent land areas in two phases. The first phase was intended to provide information throughout the Upper Estuary, while the second was intended to provide more detailed information in the pilot study area. Only those borings designated as being taken on water by Woodward-Clyde Consultants (1987) were considered in this evaluation. Locations of those borings are indicated by grid cell as shown in Figure B4. Borings for Phase I, designated by BW in Figure B4, were advanced to a depth of 20 to 40 ft using conventional methods. Samples were generally taken at 5-ft intervals with a 1-3/8-in.-diam. split spoon. Borings for Phase II, designated PD in Figure B4, were taken using the same procedure for locations PD-1, 2, 6, 7, 10-12, 14, and 17. Additionally for Phase II, Van Veen grab samples of the upper 6 in. of material and 3-in.-diam tube samples taken with a gravity corer to a depth of 5 ft were obtained at these and other locations within the Pilot Study cove.

Hot spot sampling

14. Additional push tube sampling was later conducted by NED in an area designated as the hot spot area. A total of 47 push tubes were taken in the

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* See References at the end of the main text.

same manner as those previously taken throughout the Upper Estuary. The grids in which the tubes were taken are indicated in Figure B5.

Pilot Study sampling

15. Core borings were taken by NED within and adjacent to the areas designated as dredging areas and disposal areas for the Pilot Study. Nineteen core borings were taken. In addition, 12 sediment cores were taken within the Pilot Study dredging areas to the anticipated depth of dredging. Dredging areas (DA) I and II in Figure B5 were considered to correspond to grid cells E25 and F26, respectively, for purposes of this sediment characterization.

Laboratory Testing

Push tube samples

16. A total of 39 of the NED push tubes were randomly selected for analysis and opened; visual classifications were determined. Based on the visual classifications, samples representative of 31 segments of the tubes were analyzed for physical and engineering properties. A total of 19 of the push tube samples were composited from within the 0- to 2-ft segment of the tube, and these samples are considered representative of the material to be dredged and disposed of as contaminated. A total of 12 segments were composited from within the 2- to 4-ft segment or from within the 0- to 4-ft segment, and these samples are considered representative of the cleaner underlying sediments. The remainder of the tubes were archived for additional analyses as required.

17. Tests on push tube samples included percent moisture (converted to engineering water content, the ratio of weight of water to weight of solids), Atterberg limits, grain size, and particle specific gravity. Samples were then classified using the Unified Soil Classification System (USCS).

Split spoon samples

18. Laboratory test results of Van Veen and push tube samples taken during the geotechnical investigation were not considered in this sediment characterization. Borings taken on land were also not considered.

19. All samples obtained from the split spoon borings were visually classified, and grain size distribution was determined. Based on these results, selected samples were analyzed for Atterberg limits, specific gravity, and natural water content. Samples obtained at the 0- to 2-ft depth

interval were considered to be representative of the material to be dredged and disposed as contaminated. Samples obtained at deeper intervals were considered representative of the cleaner underlying sediments to be used as cap material. It was assumed that material at a depth below 10 ft would not be dredged. Therefore, samples from below the 10- to 12-ft depth interval were not considered in this sediment characterization. However, these data are necessary for purposes of dike design, etc.

Hot spot samples

20. Samples from the hot spot cores were paired by sediment depth of 0 to 12 in. and 12 to 24 in. Physical tests consisting of water content determination and grain size distribution were conducted on samples from 15 cores. No USCS classifications were determined. These samples were considered representative of the material to be dredged as contaminated.

Pilot study samples

21. Samples from 7 of the 19 core borings taken from the Pilot Study area were analyzed for grain size distribution. These samples were taken at the 0- to 1-, 1- to 2-, and 2- to 4-ft depths. Samples from the 12 sediment cores taken within the dredging areas were analyzed for grain size distribution and water content. These samples were taken at the 0- to 2-, 2- to 4-, and 4- to 6-ft depths. No USCS classifications were determined for these core samples.

Summary

22. In summary, data from samples of the upper 2 ft of contaminated material are available from both the push tubes and split spoon samples and from the hot spot and Pilot Study sampling. Data from the 2- to 4-ft layer, considered clean material, are available only from the push tube samples and Pilot Study cores. Data from deeper layers, generally the 5- to 7-ft and 10- to 12-ft layers, are available only from the split spoon samples.

Test Results

USCS classification

23. Visual classifications and classifications using results of the grain size distribution and plasticity tests as described below were determined using the USCS.

24. The USCS classifications of samples from the 0- to 2-ft layer, considered contaminated, are shown in Figure B6. These include classifications from both the push tubes and split spoon samples. Of 36 samples analyzed, 21 were classified as organic silts or clays (OH or OL). These samples were located primarily along the west bank and cove areas of the Upper Estuary and within the Pilot Study cove. The remaining 15 samples were classified as silty sands or silts (SM or ML). These samples were located primarily along the east bank and cove areas of the estuary.

25. The USCS classifications of samples from the 2- to 4-ft layer, considered the clean layer, are shown in Figure B7. Of 15 samples analyzed, 13 were classified as organic silts or clays (OH or OL). Only two samples were classified as silty sands (SM) in the 2- to 4-ft layer. Note that by comparing Figures B6 and B7, the sample locations classified as SM in the 0- to 2-ft layer were generally not tested in the 2- to 4-ft layer. This distribution of samples analyzed causes all data for the 2- to 4-ft layer to indicate finer material, when in fact, the material for 2 to 4 ft is essentially the same for the fine-grained sample locations.

26. The USCS classifications of samples from the 5- to 7-ft layer are shown in Figure B8. Of 18 samples analyzed, only seven were classified as organic silts (OH). The remaining 11 samples were classified as silty sands or sands (SM or SP).

27. Classifications for the 10- to 12-ft layer are shown in Figure B9. Of 12 samples analyzed, 11 were classified as SM or SP, with only one sample classified as OH. These data indicate that more sandy material is predominant at sediment depths exceeding 5 ft.

Grain size distribution and percent coarse-grained

28. Grain size distribution. Grain size distributions were determined on the samples using standard sieve and hydrometer analyses. The range of grain size distributions for the push tube samples from the 0- to 2-ft depth layer (contaminated sediment) was similar to that for the split spoon samples. All the curves have been combined into one plot, shown as Figure B10. This range incorporates curves from 75 samples.

29. In a similar manner, the ranges of grain size distributions for the 2- to 4-ft layer have been combined into one plot, shown as Figure B11. This range incorporates curves from 26 samples. Comparison of Figures B10 and B11

indicates that ranges of grain size distributions for the contaminated and underlying clean sediment down to a depth of 5 ft are similar.

30. The ranges for samples from the 5- to 7-ft and 10- to 12-ft layers are combined in Figure B12. This range incorporates curves from 18 samples. Comparison of Figures B10 and B11 with Figure B12 indicates that the samples from depth below 5 ft are coarser than the surficial sediments.

31. Percent coarse-grained. The percentage of coarse-grained particles is an important parameter in evaluation of sediment resuspension and settling behavior and the volumetric changes occurring following dredging and disposal. Coarse-grained is defined as that particle fraction coarser than fine sand as defined by the USCS (retained on a No. 200 sieve or 0.074 mm).

32. Percentages of sand are shown for individual grid cells for the contaminated sediment (0- to 2-ft layer) in Figure B13. These data show that the average percent sand for the samples analyzed is approximately 43 percent. Even though the majority of the samples in this layer were classified as organic silt or clay, the material contains a significant fraction of sand. Since samples were not analyzed for each grid cell, and dredging and disposal evaluations are to be done by cell, values of percent sand have been assigned to all cells. The values were assigned as equal to the closest sample value or by interpolation between samples. These values are tabulated in Figure B14.

33. In a similar manner, values of percent sand are shown for the 2- to 4-ft layer in Figure B15. These data show that the average percent sand for the samples analyzed is approximately 27 percent. This lower value in comparison with the 0- to 2-ft layer may be indicative of the fact that few samples taken along the east bank of the estuary, generally coarser, were analyzed for the 2- to 4-ft depth. Values were similarly assigned to nonsample cells for the 2- to 4-ft layer and are shown in Figure B16.

34. Values for percent sand for samples at the 5- to 7-ft depth interval are shown in Figure B17. These data show that the average percent sand at this depth interval is approximately 56 percent. Values were similarly assigned to nonsample cells for the 5- to 7-ft layer and are shown in Figure B18.

35. The values of percent sand for the 10- to 12-ft layer are shown in Figure B19. The average value is approximately 73 percent. Since this material is predominantly a sand, for purposes of disposal it could be assumed

that the same volume occupied in the channel would be occupied in a disposal site, either for the CAD or CDF alternatives. Therefore, assigned values for nonsampled cells are not necessary.

Plasticity

36. Liquid limits and plastic limits were determined for push tube and split spoon samples using standard soils testing procedures. Plasticity indexes were then computed. Results for the various layers are plotted on the plasticity chart shown in Figure B20. Results for the 0- to 2-ft and 2- to 4-ft layers show a wide but similar range of plasticity. All results fall along the "A" line. The average liquid limits for the 0- to 2-ft layer and 2- to 4-ft layer are 105 and 117, respectively. The few fine-grained samples analyzed in the 5- to 7-ft layer are of relatively lower plasticity, with an average liquid limit of 68.

Water content

37. The in situ water content of fine-grained sediment samples is also an important parameter in evaluating settling behavior and the volumetric changes occurring following dredging and disposal. It should be noted that the water content as used here is the term normally used in geotechnical engineering, defined as the ratio of weight of water to weight of solids expressed as a percent. Water contents so defined can exceed 100 percent.

38. Values of the in situ water content are shown tabulated for individual grid cells for the contaminated sediment (0- to 2-ft layer) in Figure B21. It should be noted that values for the push tube samples were converted to water content using values of percent moisture reported by Condike (1986). These data show that the average water content for the samples analyzed is approximately 111 percent. Values assigned to nonsample cells are tabulated in Figure B22.

39. In a similar manner, values of water content are shown for the 2- to 4-ft layer in Figure B23. These data show that the average water content for the samples analyzed is approximately 128 percent. This higher value in comparison with the 0- to 2-ft layer may be indicative of the fact that few samples taken along the east bank of the estuary, generally coarser, were analyzed for the 2- to 4-ft depth. Values were similarly assigned to nonsample cells for the 2- to 4-ft layer and are shown in Figure B24.

40. Values for water content for samples at the 5- to 7-ft depth interval are shown in Figure B25. Many of the samples for this interval were

sand, and no water content was determined. Values of water content were determined for some sand samples and ranged from 21 to 24 percent. However, these data would not be indicative of the behavior of the fine-grained fraction of material for purposes of disposal evaluation for sizing, etc. The average value of the remaining three samples, 109 percent, is considered representative for this purpose.

41. No values for water content are given for samples from the 10- to 12-ft interval since this material is predominantly sand.

Sediment Characterization

Comparisons of sediment layers

42. Based on the field investigations and laboratory testing described above, the sediments to be dredged are a mixture of organic silts and clays with sand, sandy silts, and silty sands. A generalized sediment profile and a summary of the most pertinent physical and engineering properties are presented in Figure B26.

43. Comparison of the data for the 0- to 2-ft depth layer, representative of the contaminated sediments, and the 2- to 5-ft depth layer, representative of the upper portion of the underlying clean sediments, indicates that the sediments to be dredged are similar from a physical standpoint. At depths below 5 ft, the sediments are generally coarser, with sand predominant at depths exceeding 10 ft. These delineations are shown in Figure B26.

44. Grain size data indicate that the contaminant sediments have an average percent sand of 43 percent, a significant fraction even though the USCS classification is fine-grained. Underlying clean sediments at the 2- to 5-ft depth have an average percent sand of 27 percent, though this lower value is likely an artifact of the distribution of samples analyzed. This distribution of grain sizes is similar for both sediment types. Percent sand for sediments at the 5- to 10-ft and below 10-ft layers increases to 53 and 74 percent, respectively.

45. Plasticity data indicate that the fine-grained fractions of the contaminated and underlying clean sediments at 2 to 5 ft are similar. Average values of the liquid limit are 105 and 117 for the contaminated and clean sediments, respectively.

46. The in situ water content of the contaminated sediments is similar to the underlying clean sediments at the 2- to 5-ft depth. Average values of in situ water content are 111 and 128 percent for the contaminated and clean sediments, respectively. The in situ water content is generally slightly above the liquid limit for the fine-grained samples.

Comparison with WES composite

47. A comparison of the characteristics of the WES composite sample used for environmental and related engineering tests and the corresponding average test values of all samples from the upper 2 ft is as follows:

	Average of Samples (0- to 2-ft layer)	WES Composite
Percent sand	43	32
Water content	111	195
Liquid limit	105	129

48. The grain size distribution of the composite is shown superimposed within the range of distributions from the upper 2 ft in Figure B10. The Atterberg limits for the composite sample are also plotted on the plasticity chart in Figure B20. These comparisons show that the composite sample is slightly finer grained and of slightly higher plasticity than the average values of the upper 2 ft of sediment. Tests for settling and consolidation behavior using the WES composite sample would therefore give conservative results, i.e., slower settling or consolidation rates than would be exhibited by a sample with the average characteristics.

Considerations for dredging and disposal

49. Dredging. The engineering characterization of the sediments to be dredged indicates that, from the standpoint of dredgeability, no problems should be encountered in removing the contaminated sediments with a hydraulic pipeline dredge (MUDCAT, cutterhead, or matchbox). If CAD is chosen as a disposal alternative, and if CAD design requires removal of underlying clean sediments below a depth of 5 ft, some difficulty may be encountered using a matchbox dredge for this material. This would be due to the high percentage of sand. The matchbox has no agitation or cutting action, and has been designed to operate in primarily fine-grained sediments.

50. One factor not sufficiently defined by the engineering characterization is the potential presence of debris. The sampling and testing conducted to date indicate that no significant debris is present in the sediment mass, but debris has been visually identified, especially along the shoreline. The NED is presently evaluating this in more detail.

51. CDF disposal. The engineering characterization of the sediments to be dredged indicates that no problems should be encountered with pipeline transport and disposal in a CDF. Since only a relatively small volume of underlying clean sediments would be dredged with a CDF alternative, all the sediments to be dredged would be similar from a physical and engineering standpoint for the CDF alternative. The fraction of coarse-grained material present, 27 to 43 percent, will cause buildup of material at the pipeline influent location. Frequent movement of the pipeline should be anticipated. For placement of the surface cap, maintenance of a ponded condition and movement of the influent using a floating pipeline and splashplate should be considered. Due to the significant portion of sand present in the sediments, the changes in volume following dredging and placement in a CDF should be small in comparison with projects that involve predominantly fine-grained, claylike material. Previous rough estimates of a bulking factor of 2.0 are likely too high. Sizing of disposal areas for storage volume should be based on methods described in Engineer Manual 1110-2-5027 (USACE 1987).

52. CAD disposal. The engineering characterization of the sediments to be dredged indicates that resuspension and transport of material during CAD placement operations should be limited to the immediate vicinity of the operation. The significant fraction of coarse-grained material in the contaminated sediments should indicate relatively quick settling within the CAD cells following discharge from the submerged diffuser. It will likely be necessary to frequently move the discharge point for placement of material within the CAD cells to avoid mounding of the coarse-grained fraction. Since a larger volume of underlying clean sediments will be dredged for CAD as compared with a CDF alternative, the sediments will likely be removed from depths exceeding 5 ft from at least a portion of the project. This would mean that the cap for the CAD cells may be primarily a sand material for one or more cells.

53. Sizing for storage for the CAD alternative involves processes similar to those for a CDF. The same considerations as described above with regard to CDF sizing also apply to the CAD alternative.

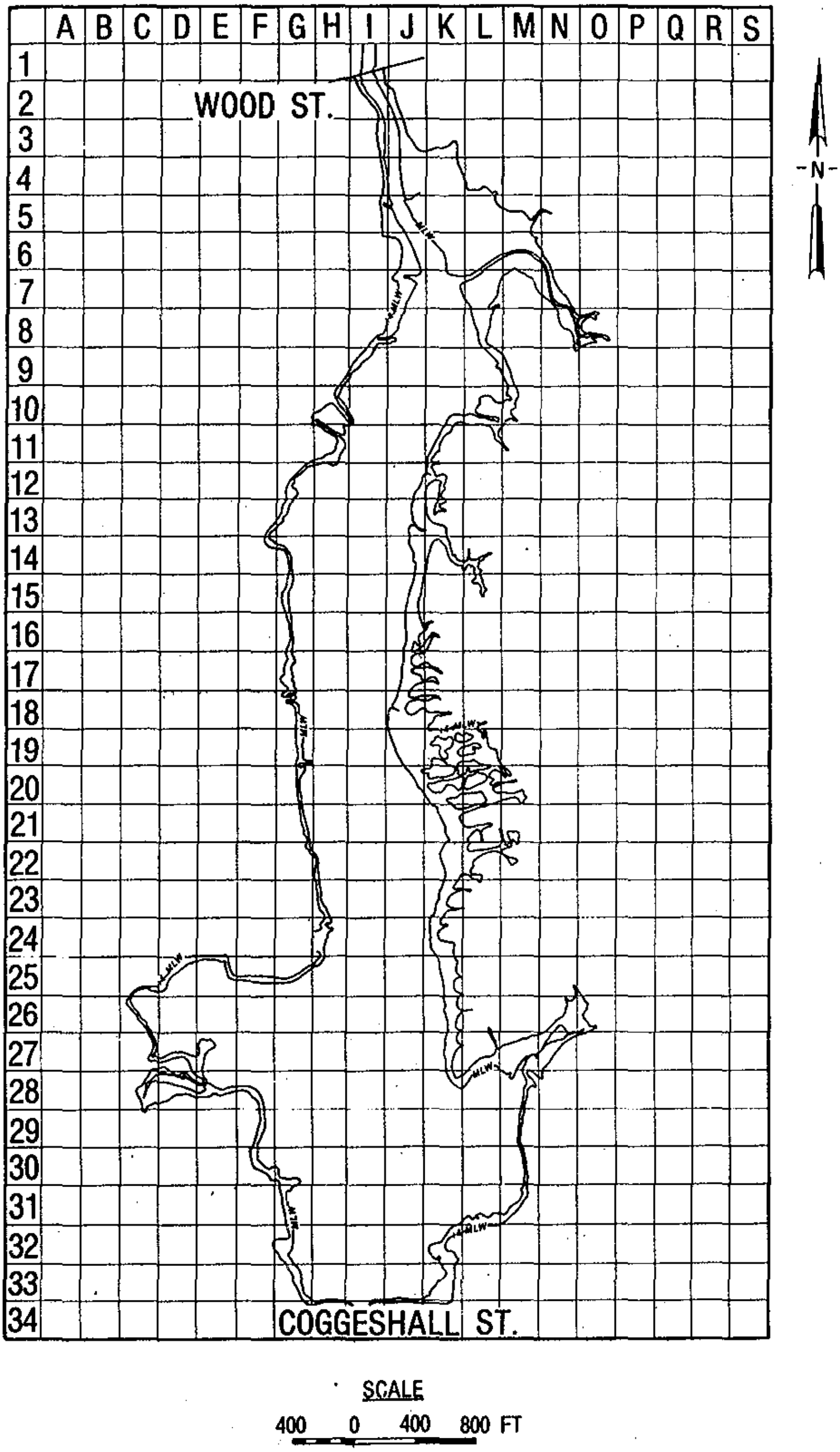

Figure B1. Upper Estuary grid system used in the EFS

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								0.50	0.13				
3								0.22	0.50				
4								0.15	1.00	0.82	0.10		
5								0.02	1.00	1.00	0.95		
6									0.42	1.00	1.00	0.93	0.05
7									0.50	1.00	0.77	0.36	0.30
8								0.05	0.85	1.00	0.56		
9							0.03	0.78	1.00	1.00	0.94	0.05	
10							0.18	1.00	1.00	0.98	0.94	0.20	
11							0.29	1.00	1.00	0.28			
12						0.43	1.00	1.00	0.96	0.16			
13					0.03	0.82	1.00	1.00	0.94	0.11			
14					0.02	0.69	1.00	1.00	0.94				
15						0.62	1.00	1.00	0.74				
16						0.54	1.00	1.00	0.82				
17						0.53	1.00	1.00	0.74				
18						0.37	1.00	1.00	0.77				
19						0.26	1.00	1.00	1.00				
20						0.30	1.00	1.00	0.96	0.43			
21						0.21	1.00	1.00	1.00	0.93			
22						0.02	0.91	1.00	1.00	0.95			
23							0.76	1.00	1.00	0.56			
24							0.61	1.00	1.00	0.50			
25		0.10	0.61	0.82	0.40	0.48	0.94	1.00	1.00	0.77			
26		0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.77			
27		0.06	0.53	0.82	1.00	1.00	1.00	1.00	1.00	0.75	0.38	0.82	
28		0.08	0.27	0.40	0.64	1.00	1.00	1.00	1.00	0.98	1.00	0.51	
29					0.26	1.00	1.00	1.00	1.00	1.00	1.00	0.42	
30					0.21	0.85	1.00	1.00	1.00	1.00	1.00	0.50	
31						0.59	1.00	1.00	1.00	0.98	0.80	0.20	
32						0.48	1.00	1.00	1.00	0.37			
33						0.18	1.00	1.00	1.00	0.32			

Figure B2. New Bedford area factors

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								I3					
3													
4									J5	K5			
5												M6	
6													
7									J8				
8								I9					
9											L10		
10								I11					
11													
12						G13			J13				
13													
14								I15	J15				
15													
16						G17			J17				
17													
18								I19					
19						G20			J20				
20							H21						
21													
22								I23					
23													
24				E25			H25						
25										K26			
26				E27								M27	
27								I28		K28			
28						G29					L29		
29													
30								I31					
31										K32			
32							H33						
33													

Figure B3. New Bedford push tube locations

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5											BW-1		
6													
7													
8													
9									BW-2				
10								BW-3					
11													
12													
13													
14													
15													
16									BW-5				
17						BW-4							
18													
19								BW-6					
20													
21													
22										BW-7			
23													
24													
25			PD-1			PD-7	PD-10	BW-8					
26			PD-2		PD-6		PD-11						
27					PD-17	BW-9	PD-12					BW-14	
28													
29								BW-10		BW-11			
30						BW-12	PD-14			BW-13			
31													
32													
33													

Figure B4. New Bedford boring locations, Phases I (BW) and II (PD)

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5													
6													
7									HS				
8								HS	HS				
9									HS				
10							HS		HS				
11							HS	HS					
12						HS		HS					
13							HS	HS					
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25				DAI									
26					DAII								
27													
28													
29													
30													
31													
32													
33													

Figure B5. New Bedford sample locations for hot spot push tubes and Pilot Study borings

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5									SC	OH	ML-OL		
6													
7													
8									OH				
9								OH	ML-OL				
10								OH					
11								OH					
12													
13						OH			SM-SC				
14													
15									SM				
16									SM				
17						OH			SC				
18													
19								OH-OH					
20						OH			SM				
21													
22										SW			
23													
24													
25				OH			OH	OH					
26										SM			
27				OH	OH	SM	OL					SW	
28										SC			
29							OL-OH	OL-OH		OL			
30						OL	OH						
31								SC		OL			
32										SM			
33													

Figure B6. New Bedford primary classifications from 0 to 2 ft

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3								SM					
4													
5													
6												OH	
7													
8													
9													
10											OH		
11													
12													
13													
14													
15								OH					
16													
17						OH							
18													
19													
20													
21							OH						
22													
23								OH					
24													
25													
26													
27					OH		OL					SM	
28								OH					
29						OH	OL				OH		
30													
31													
32													
33							OH						

Figure B7. New Bedford primary classifications from 0 to 4 ft

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5											SM		
6													
7													
8													
9													
10								OH					
11													
12													
13													
14													
15													
16													
17									SP				
18						Pt							
19								OH					
20													
21													
22										SM			
23													
24													
25			SM			SM	SM	OH					
26			OH		OH		SM						
27						SP-SM						SP-SM	
28													
29								OH		SM			
30							OH						
31													
32													
33													

Figure B8. New Bedford primary classifications from 5 to 7 ft

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5											SP-SM		
6													
7													
8													
9													
10								OH					
11													
12													
13													
14													
15													
16									SP				
17						SM							
18													
19								SW					
20													
21													
22										SM			
23													
24													
25								SM					
26													
27							SM					SM	
28													
29								SP		SM			
30										SM			
31													
32													
33													

Figure B9. New Bedford primary classifications from 10 to 12 ft

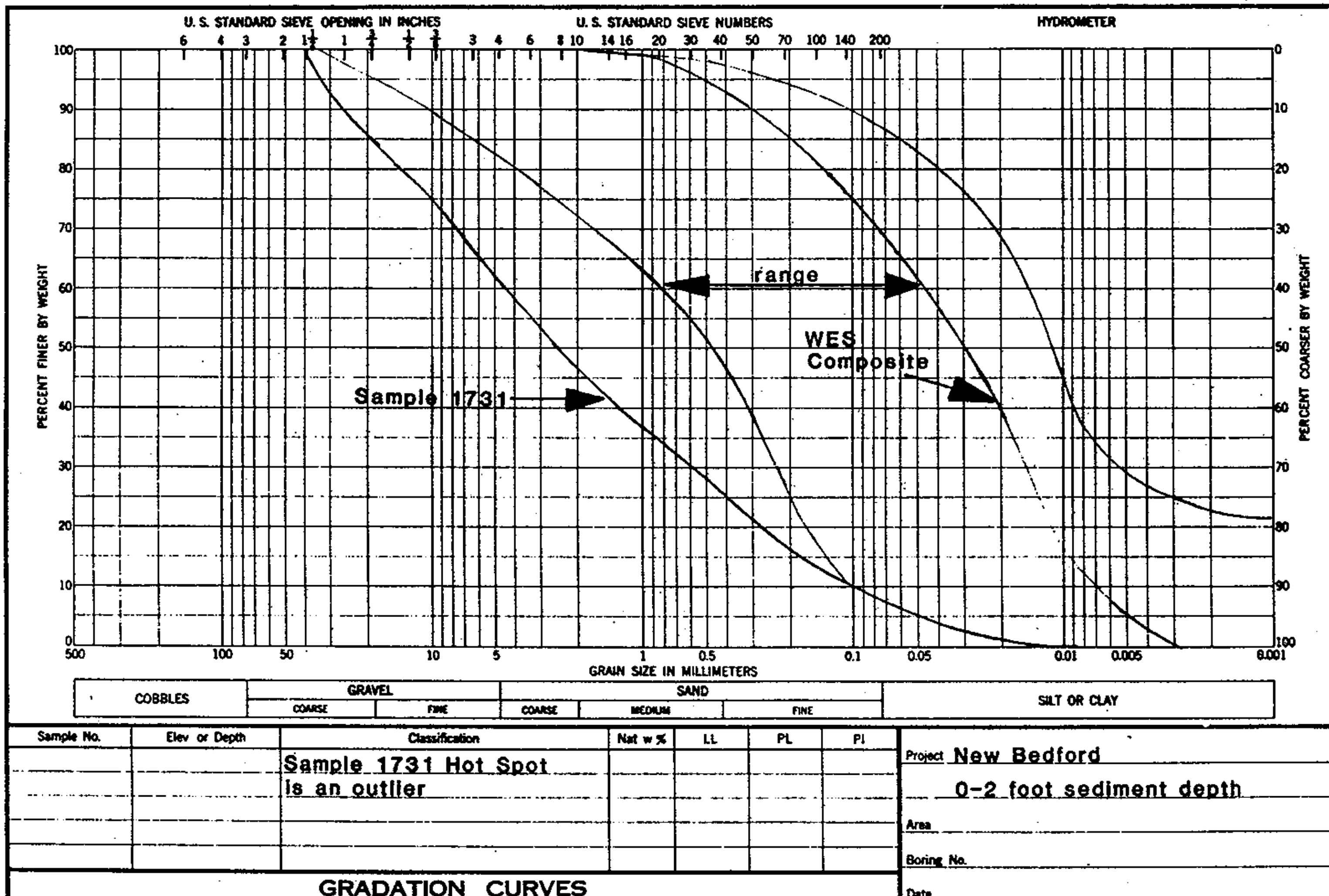

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Figure B10. Gradation curves for New Bedford 0- to 2-ft sediment depth

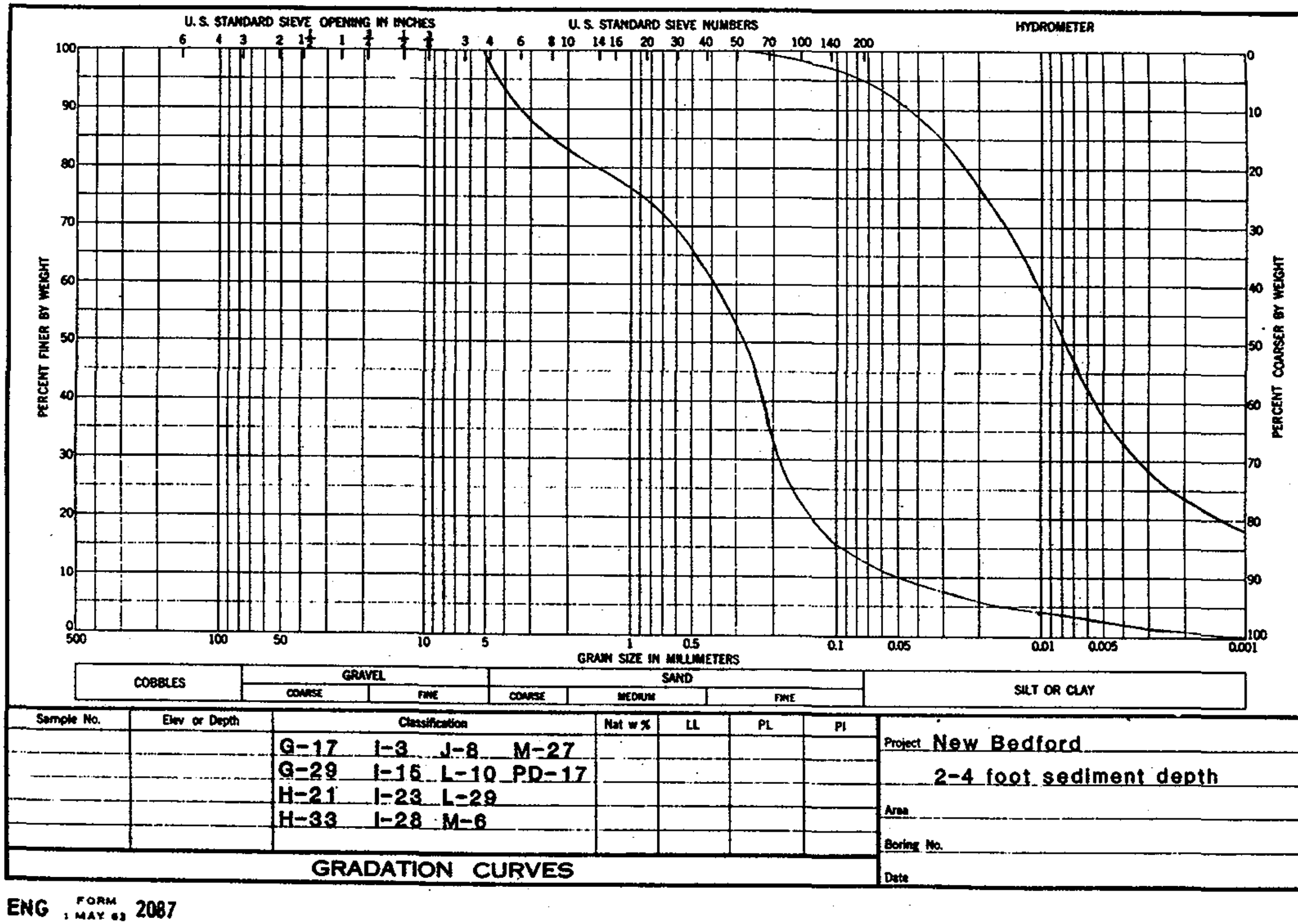


Figure B11. Gradation curves for New Bedford 2- to 4-ft sediment depth

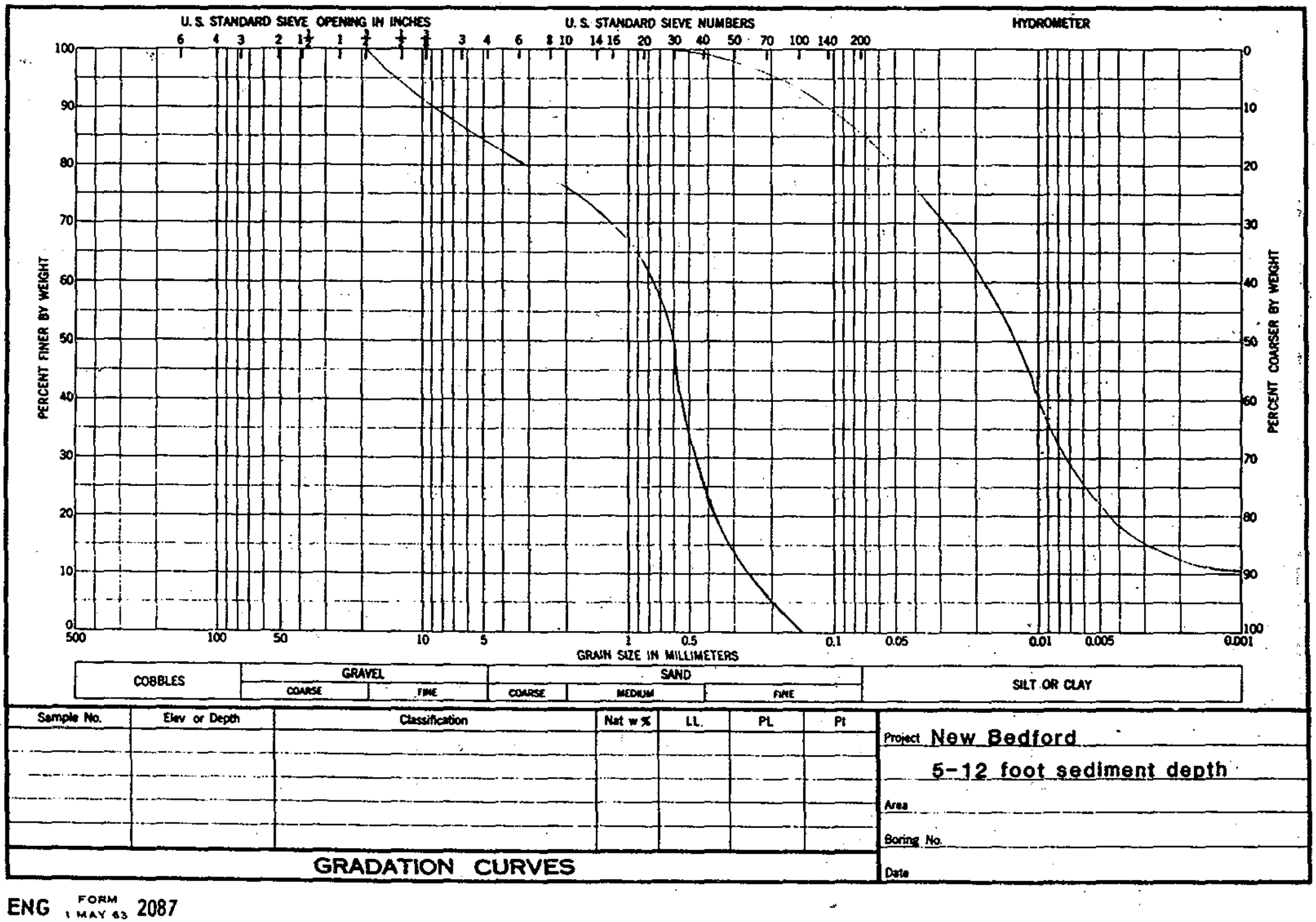


Figure B12. Gradation curves for New Bedford 5- to 12-ft sediment depth

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5									62	15	22		
6													
7									67				
8								37	41				
9								25	64				
10							21	24	43				
11							24	19					
12						58		17					
13						23	20	20	69				
14													
15									72				
16									86				
17						14			53				
18													
19								28					
20						26			87				
21													
22										92			
23													
24													
25				30			30	14					
26					22					79			
27				32	20	60	44					64	
28										73			
29							38	23		43			
30						43	33						
31								79		41			
32										80			
33													

Figure B13. New Bedford percent sand in the 0- to 2-ft layer

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								62	62				
3								62	62				
4								62	62	15	22		
5								62	62	15	22		
6									62	15	22	22	22
7									67	67	51	22	22
8								37	41	41	51		
9							25	25	64	64	51	51	
10							21	24	43	43	51	51	
11							24	19	43	43			
12						58	23	17	69	69			
13					23	23	20	20	69	69			
14					23	23	18	70	70				
15						18	18	78	72				
16						14	14	86	86				
17						14	14	53	53				
18						14	14	28	53				
19						26	27	28	57				
20						26	26	28	87	87			
21						26	26	28	87	92			
22						26	26	40	90	92			
23							30	14	52	92			
24							30	14	14	85			
25		30	30	30	30	30	30	14	14	79			
26		30	30	31	22	60	37	14	47	79			
27		32	32	32	20	60	44	44	48	76	64	64	
28		32	32	32	20	60	40	23	48	73	73	64	
29					20	43	38	23	33	43	43	64	
30					43	43	33	51	55	42	42	64	
31						43	33	79	60	41	41	64	
32						43	33	79	80	80			
33						43	33	79	79	80			

Figure B14. New Bedford percent sand in the 0- to 2-ft layer with nonsample cell locations added

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3								61					
4													
5													
6												14	
7													
8													
9													
10											4		
11													
12													
13													
14													
15								14					
16													
17						12							
18													
19													
20													
21							12						
22													
23								25					
24													
25													
26													
27					23							80	
28								14					
29						18	37				17		
30													
31													
32													
33							35						

Figure B15. New Bedford percent sand in the 2- to 4-ft layer

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								61	61				
3								61	61				
4								61	61	14	14		
5								61	61	14	14		
6									61	14	14	14	14
7									61	14	14	14	14
8									61	14	14		
9							61	61	61	4	4	4	
10							61	14	14	4	4	4	
11							61	14	14	4	4		
12						12	13	14	14	4			
13						12	13	14	14	4			
14						12	13	14	14	4			
15						12	13	14	14				
16						12	13	14	14				
17						12	13	14	14				
18						12	12	14	14				
19						12	12	25	25				
20						12	12	25	25	25			
21						12	12	25	25	25			
22						12	12	25	25	25	25		
23							25	25	25	25			
24							25	25	25	25			
25		50	50	50	21	21	25	14	14	25			
26		50	50	50	21	21	25	14	14	17			
27		50	50	50	23	18	20	14	14	17	80	80	
28		50	50	50	23	18	37	14	14	17	17	80	
29					23	18	37	14	14	17	17	80	
30					18	18	37	14	14	17	17	80	
31						18	36	35	35	17	17	80	
32						35	35	35	35	17			
33						35	35	35	35	17			

Figure B16. New Bedford percent sand in the 2- to 4-ft layer with values assigned to nonsample cells

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5											84		
6													
7													
8													
9													
10								16					
11													
12													
13													
14													
15													
16									98				
17						91							
18													
19								19					
20													
21													
22										63			
23													
24													
25			86			77	69	21					
26			19		14		71						
27						93						91	
28													
29								25		66			
30							17						
31													
32													
33													

Figure B17. New Bedford percent sand in the 5- to 7-ft layer

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								84	84				
3								84	84				
4								84	84	84	84		
5								84	84	84	84		
6									84	84	84	84	84
7									84	84	84	84	84
8								16	16	84	84		
9							16	16	16	84	84	84	
10							16	16	16	84	84	84	
11							16	16	16	84			
12						23	16	16	16	84			
13					23	23	16	16	98	87			
14					23	23	23	16	98				
15						23	23	98	98				
16						23	23	98	98				
17						23	23	19	98				
18						23	23	19	98				
19						23	19	19	19				
20						23	19	19	19	19			
21						23	19	19	63	63			
22						23	69	21	63	63			
23							69	21	63	63			
24							69	21	21	63			
25		86	86	60	14	77	69	21	21	63			
26		86	19	30	14	85	71	21	21	63			
27		86	19	16	14	93	71	23	46	66	78	91	
28		86	19	16	14	93	44	25	46	66	78	91	
29					14	93	17	25	46	66	78	91	
30					14	93	17	25	46	66	78	91	
31						17	17	25	46	66	78	91	
32						17	17	25	46	66			
33						17	17	25	46	66			

Figure B18. New Bedford percent sand in the 5- to 7-ft layer with values assigned to nonsample cells

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5											94		
6													
7													
8													
9													
10								17					
11													
12													
13													
14													
15													
16									98				
17						61							
18													
19								70					
20													
21													
22										64			
23													
24													
25								78					
26													
27							93					74	
28													
29								97		53			
30										81			
31													
32													
33													

Figure B19. New Bedford percent sand in the 10- to 12-ft layer

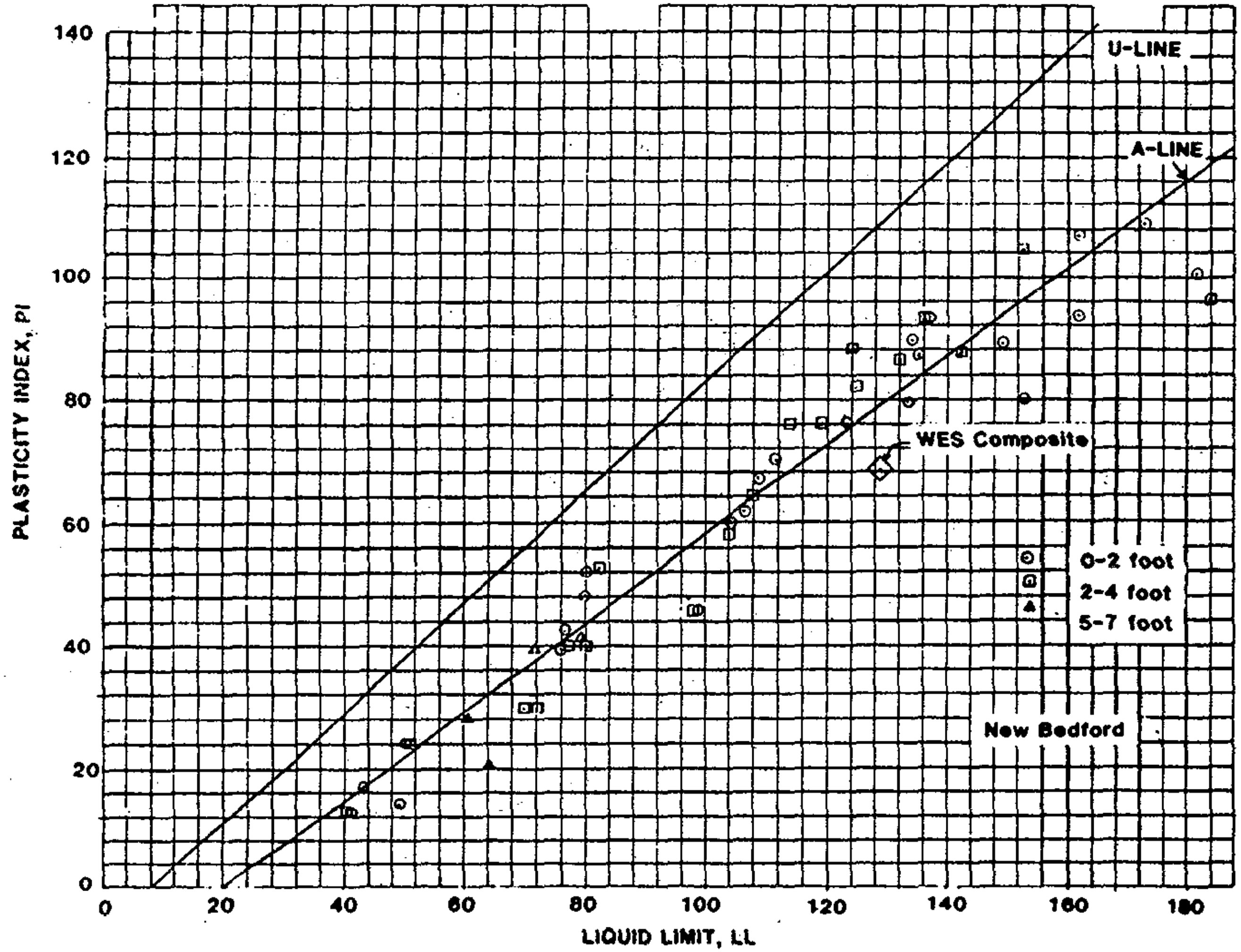


Figure B20. Plasticity chart for New Bedford sediment

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5									100	194	123		
6													
7											56		
8										143	158		
9										185			
10									117				
11									169	172	169		
12								110		162			
13								112	143		41		
14													
15											69		
16										91	31		
17								177			108		
18													
19										203			
20								127			32		
21													
22												27	
23													
24													
25					133				156	161			
26						159						23	
27					112				101				44
28												32	
29									131	133		89	
30								86					
31										45			
32												43	
33													

Figure B21. New Bedford water contents in the 0- to 2-ft layer

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								100	100				
3								100	100				
4								100	100	194	123		
5								100	100	194	123		
6									100	194	123	123	123
7									56	194	123	123	123
8								143	158	158	158		
9							152	185	158	158	158	158	
10							117	179	179	158	158	158	
11							169	172	41	41			
12						110	152	162	41	41			
13					112	112	143	203	41	41			
14					112	112	143	69	55				
15						143	91	91	69				
16						177	91	91	31				
17						177	177	91	108				
18						177	177	203	108				
19						167	203	203	32				
20						127	127	203	32	32			
21						127	143	203	32	27			
22						127	143	181	32	27			
23							156	161	161	27			
24							156	161	161	25			
25		133	133	133	146	156	156	161	164	23			
26		122	122	122	159	151	123	161	23	23			
27		122	112	112	135	101	101	146	89	27	44	44	
28		122	112	112	112	116	116	133	89	32	44	44	
29					86	86	131	133	89	89	44	44	
30					86	86	131	133	89	89	44	44	
31						86	45	45	44	43	44	44	
32						86	45	45	44	43			
33						86	45	45	44	43			

Figure B22. New Bedford water content in the 0- to 2-ft layer with values assigned to nonsample cells

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3								47					
4													
5													
6												257	
7													
8													
9													
10											117		
11													
12													
13													
14													
15								127					
16													
17						222							
18													
19													
20													
21							170						
22													
23								143					
24													
25													
26													
27												37	
28								143					
29						117					132		
30													
31													
32													
33							93						

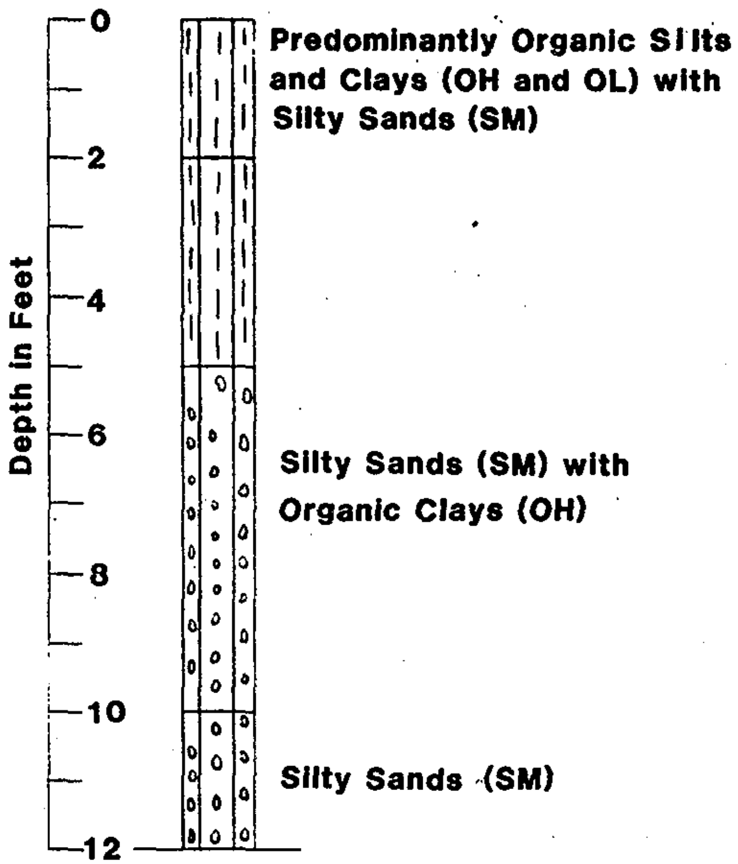
Figure B23. New Bedford water contents in the 0- to 4-ft layer

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2								47	47				
3								47	47				
4								47	47	257	257		
5								47	47	257	257		
6									47	257	257	257	257
7									47	257	257	257	257
8								47	47	257	257		
9							127	127	127	117	117	117	
10							127	127	127	117	117	117	
11							127	127	127	117			
12						222	127	127	127	117			
13					222	222	127	127	127	117			
14					222	222	127	127	127				
15						222	127	127	127				
16						222	222	127	127				
17						222	222	127	127				
18						222	222	127	127				
19						222	222	127	127				
20						170	170	170	143	143			
21						170	170	170	143	143			
22						170	170	170	143	143			
23							143	143	143	143			
24							143	143	143	143			
25		74	74	74	117	117	143	143	143	143			
26		74	74	74	117	117	143	143	143	143			
27		74	74	74	117	117	143	143	143	143	37	37	
28		74	74	74	117	117	143	143	143	143	132	37	
29					117	117	143	143	143	132	132	132	
30					117	117	143	143	143	132	132	132	
31						93	93	93	93	132	132	132	
32						93	93	93	93	132			
33						93	93	93	93	132			

Figure B24. New Bedford water contents in the 0- to 4-ft layer with values assigned to nonsample cells

A	B	C	D	E	F	G	H	I	J	K	L	M	N
2													
3													
4													
5											24		
6													
7													
8													
9													
10								105					
11													
12													
13													
14													
15													
16													
17						21							
18													
19								112					
20													
21													
22										21			
23													
24													
25													
26													
27						21						21	
28													
29										23			
30							109						
31													
32													
33													

Figure B25. New Bedford water contents in the 5- to 7-ft layer



AVERAGE VALUES

Percent Sand	Water Content %	Liquid Limit
43	111	105
27	128	117
53	109	68
74	---	---

Figure B26. Average physical characteristics of estuary sediment

APPENDIX C: COST ESTIMATES FOR DREDGING AND DISPOSAL ALTERNATIVES

Introduction

1. This appendix contains cost estimates for the dredging and dredged material disposal alternatives and design options discussed in this report. These estimates include costs associated with the design of various components of each alternative, preparation of plans and specifications, administration of the construction contract, inspection of construction activities, and operation and maintenance. The appendix is divided into three sections: *dredging and disposal alternatives, confined disposal facilities, and dredging* cost estimates.

2. This format will allow for a more detailed discussion of the components of each alternative.

Dredging and Disposal Alternatives

3. *Cost estimates were developed for six of the seven alternatives* described in the report. Four of these alternatives involve disposal of the contaminated sediments in confined disposal facilities (CDF) only. The other two alternatives involve disposal of contaminated sediment in both CDFs and contained aquatic disposal (CAD) cells.

Option A

4. This option involves constructing unlined CDFs at site 1, 1B, 3, and 12. The construction sequence is shown in Figure C1. It is estimated that approximately 5.75 years would be required to complete this effort. The total first cost is estimated at $27,683,500; a breakdown of this cost is given in Table C1.

Option B

5. This option also involves constructing unlined CDFs at sites 1, 1B, 3, and 12. It differs from option A in that contaminated dredged material would be removed from site 1B prior to the construction of a CDF at that location. It is estimated that approximately 6.75 years would be required to complete this effort at an estimated first cost of $28,053,991. The construction sequence is shown in Figure C2, with the price breakdown shown in Table C2.

Option C

6. This option involves constructing lined CDFs at sites 6 and 12 and unlined CDFs at sites 1 and 3. Approximately 6.25 years would be required to complete this effort at an estimated first cost of $30,530,712. The construction sequence is shown in Figure C3, with the price breakdown shown in Table C3.

Option D

7. This option involves constructing lined CDFs at sites 1, 1B, 3, 6, and 12. Contaminated sediment from sites 1, 1B, and 3 would also be removed prior to the construction of CDFs at these locations. Approximately 12.5 years would be required to complete this effort at an estimated first cost of $50,386,778. The construction sequence is shown in Figure C4, with the price breakdown shown in Table C4.

CAD Option A

8. This option involves constructing unlined CDFs at sites 1, 1A, and 3. A temporary CDF would also be constructed at site 12 to store clean cap material. Approximately 8.25 years would be required to complete this effort at an estimated first cost of $33,200,072. The construction sequence is shown in Figure C5, with the price breakdown shown in Table C5.

CAD Option B

9. This option involves constructing unlined CDFs at sites 1 and 1A. Temporary CDFs would also be constructed at sites 6 and 12 to store clean cap material. Approximately 10.5 years would be required to complete this effort at an estimated first cost of $34,797,333. The construction sequence is shown in Figure C6, with the price breakdown shown in Table C6.

Confined Disposal Facilities

10. Cost estimates were developed for constructing CDFs at the six locations described in the report. The following paragraphs provide a brief description of the physical characteristics and the assumptions made in computing the cost estimates for each site. Line item cost breakdowns for all sites are provided in Tables C7 through C17. Additional cost items for CDF effluent treatment and operation and maintenance are summarized in Table C18.

Site 1 unlined

11. Site characteristics are as follows:

Capacity		270,000 cu yd*
Approximate surface area		926,000 sq ft
Linear feet of dike	- in water	950 ft
	- land	1,750 ft

a. Refer to Figures 19 and 20 of the main text for typical dike cross sections.

b. The in-water section of the dike will be constructed in two stages with a geotextile placed along the dike alignment prior to the placement of any fill.

c. A secondary cell of approximately 10,000 sq ft will be constructed within the CDF. Sheet-pile walls will separate the two cells with the sheets being approximately 30 ft in length.

d. Geotechnical monitoring (piezometers, settlement plates, etc.) would be required for the in-water dike section.

e. Stone protection will be provided along the face of the in-water dike up to elevation +8.0 mean low water.

f. The outside face of the land dike and a strip along the perimeter of the site will be topsoiled and seeded.

g. A 2-ft-thick cap would be placed on the site and the site topsoiled and seeded. This cap material will be from a land source. A geomembrane would be placed over the site as part of the cap.

Site 1 lined

12. Site characteristics are as follows:

a. Refer to Figures 19 and 20 of the main text for typical dike cross sections.

b. The in-water section of the dike will be constructed in three stages, with the first stage being hydraulically placed dredged material from the lower harbor. A geotextile will be placed along the dike alignment prior to the placement of any fill.

c. The site would initially be filled to elevation +6.0 mean low water with dredged material from the lower harbor. Two feet of settlement is assumed. This layer of dredged material is intended to provide a stable base for the liner.

d. A secondary cell of approximately 10,000 sq ft will be constructed within the CDF. Sheet-pile walls will separate the two cells with the sheets being approximately 70 ft in length.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5 of the main text.

e. A double sheet-pile wall would replace the granular fill dike for a 650-ft-long section along the northern side of the site. These sheets would be approximately 70 ft in length.

f. Refer to Figure 23 of the main text for a sketch of the liner cross section.

g. Refer to notes d, e, f, and g under "Site 1 unlined."

Site 1A unlined

13. Site characteristics are as follows:

Capacity		30,000 cu yd
Approximate surface area		165,600 sq ft
Linear feet of dike	- in water	950 ft
	- land	1,000 ft

a. Refer to Figures 19 and 20 of the main text for typical dike cross sections.

b. Refer to notes b and c under Site 1 unlined.

c. A double sheet-pile wall will replace the granular fill dike for a 275-ft-long section along the southern side of the site. This wall will separate the CDF from the Coggeshall Street Bridge embankment. The sheets will be approximately 40 ft in length.

Site 1B unlined

14. Site characteristics are as follows:

Capacity		90,000 cu yd
Approximate surface area		394,000 sq ft
Linear feet of dike	- in water	1,800 ft
	- land	2,000 ft

a. Refer to Figures 19 and 20 of the main text for typical dike cross sections.

b. Refer to notes b through g under Site 1 unlined.

Site 1B lined

15. Site characteristics are as follows:

a. Refer to Figures 7 and 8 of the main text for typical dike cross sections.

b. Refer to notes b, c, d, and f under Site 1 lined.

c. Refer to notes d, e, f, and g under Site 1 unlined.

Site 3 unlined

16. Site characteristics are as follows:

Capacity	134,000 cu yd
Approximate surface area	443,000 sq ft

Linear feet of dike	- in water	1,800 ft
	- land	1,700 ft

a. Refer to Figures 19 and 20 of the main text for typical dike cross sections.

b. Refer to notes b through g under Site 1 unlined.

c. A double sheet-pile wall will replace the granular fill dike for a 275-ft-long section along the southern side of the site. The wall will separate the CDF from the Coggeshall Street Bridge embankment. The sheets will be approximately 40 ft in length.

Site 3 lined

17. Site characteristics are as follows:

a. Refer to Figures 19 and 20 of the main text for typical dike cross sections.

b. Refer to notes b, c, d, and f under Site 1 lined.

c. Refer to notes d, e, f, and g under Site 1 unlined.

d. The sheets for the double sheet-pile wall along the southern side of site will be approximately 70 ft in length.

Site 6 unlined/lined

18. Site characteristics are as follows:

Capacity	100,000 cu yd
Approximate surface area	387,000 sq ft
Linear feet of dike	2,530 ft

a. Refer to Figure 21 of the main text for typical dike cross section.

b. A granular fill dike will separate the primary and secondary cells.

c. Site will require clearing and some excavation to level the site.

d. Refer to notes f and g under Site 1 unlined.

e. Refer to Figure 23 of the main text for liner cross section.

Site 12 unlined/lined

19. Site characteristics are as follows:

Capacity	325,000 cu yd
Approximate surface area	896,000 sq ft
Linear feet of dike	6,350 ft

a. Refer to Figure 21 of the main text for typical dike cross section.

b. A granular fill dike will separate the primary and secondary cells.

c. Site will require clearing and the demolition of existing structures.

d. Refer to notes f and g under Site 1 unlined.

e. Refer to Figure 23 of the main text for liner cross section.

f. Site will require the removal of contaminated sediment for the lined option.

Dredging Cost Estimates

20. Dredging costs were determined for each alternative following the approach described in the paragraphs below. The estimates were based on two MUDCAT dredges with operating personnel being onsite at all times. A production rate of 800 cu yd per day is based on the physical constraints associated with working in the Upper Estuary, the settling characteristics of the dredged material, the size of the available disposal facilities, and the operating capabilities of the *MUDCAT* dredge. Work will be performed 25 days per month, 9 months per year. Dredging would not be carried out during the winter months of December, January, and February.

21. A detailed breakdown of the dredging estimate for option A is shown below. Estimates for the other options were computed by the same method, with the differences shown in the following table.

Option	Quantity Removed cu yd	Maximum Pipeline Length, ft	Booster Pumps Required	Total Dredge Time months	$/cu yd
CDF A	665,830	5,300	1	33.54	9.65
CDF B	687,400	5,300	1	34.62	9.70
CDF C	742,100	12,000	3	37.36	11.80
CDF D	821,100	12,000	3	41.31	12.10
CAD-A	1,177,374	5,300	1	59.12	9.60
CAD-B	1,696,272	5,300	1	85.06	9.65

Detailed Dredging Estimate for CDF Option A

Production requirements

Contaminated dredged material	463,430
Dredged material to cap CDFs	202,400
Total quantity dredged material	665,830 cu yd

1.	Size of dredge pipeline	8 in.
2.	Power output - main pump	175 hp
3.	Maximum pipeline length	5,300 ft
4.	Average pipeline length	2,700 ft
5.	Number of booster pumps	1
6.	Chart production	100 cu yd/hr
7.	Net production	80 cu yd/hr
8.	Operating hours per day	10
9.	Operating days per month	25
10.	Cubic yards per month	20,000
11.	Dredge time	33.29 months
12.	Cleanup	0.25 months
13.	Total dredge time	33.54 months

Summary of costs

1.	Plant ownership costs			$ 7,689/month
2.	Operating cost			$113,799/month
3.	Pipeline costs			
	a. Floating pipeline		$1,400/month	500 ft @ $2.80/ft/month
	b. Submerged pipeline		$9,200/month	4,600 ft @ $2.00/ft/month
	c. Shoreline		$1,300/month	1,000 ft @ $1.30/ft/month
	d. Partially utilized		$2,643/month	2,600 ft @ $1.02/ft/month
4.	Booster		$ 7,500/month	
5.	Protective equipment & monitoring		$ 5,000/month	
6.	Total monthly cost		$ 148,531	
7.	Dredge time	×	33.54 months	
8.	Subtotal	=	$4,981,730	
9.	Overhead & bond (13%)	+	$ 647,625	
10.	Net pay yardage cost		$5,629,355	
11.	Mobilization/demobilization & shutdown		$ 218,592	
12.	Total dredging cost		$5,847,947	
13.	Maximum pay yardage		665,830 cy	
14.	Unit price		$ 8.78/cy	
15.	Unit price including profit		$ 9.65/cy	

Mobilization and demobilization - summary

Mobilization

		No. Days		$/Day		Total
1.	Prepare dredge for transfer	3	×	$3,452	=	$ 10,356
2.	Prepare pipeline for transfer	2	×	$2,303	=	$ 4,606
3.	Transfer all plant 200 miles @ 100 miles/day	2	×	$8,219	=	$ 16,438
4.	Insurance					$ 8,000
5.	Permanent personnel and miscellaneous					$ 3,519
6.	Prepare dredge after transfer	4	×	$3,302	=	$ 13,208
7.	Prepare pipeline after transfer	3	×	$2,153	=	$ 6,459
8.	Other - shutdown (9 months)	9	×	$7,692	=	$ 69,228
	Subtotal					$131,814

Demobilization

		No. Days		$/Day		Total
1.	Prepare dredge for transfer	3	×	$3,602	=	$ 10,806
2.	Prepare pipeline for transfer	2	×	$2,453	=	$ 4,906
3.	Transfer all plant 200 miles @ 100 miles/day	2	×	$8,219	=	$ 16,438
4.	Insurance					$ 8,000
5.	Permanent personnel and miscellaneous					$ 3,018
6.	Prepare dredge after transfer	3	×	$3,152	=	$ 9,456
7.	Prepare pipeline after transfer	2	×	$2,003	=	$ 4,006
8.	Other cleanup					$ 5,000
	Subtotal					$ 61,630
	Subtotal mobilization & demobilization					$193,444
	Overhead & bond (13%)					$ 25,148
	Total mobilization & demobilization					$218,592

Mobilization and demobilization detailed cost estimate

		Mobil.	Demob.
1.	Prepare dredge for transfer		
	6 men @ 8 hr/day @ $37.88 per hour	$1,818	$1,818
	Supplies and small tools	$ 300	$ 300
	Support equipment w/operators	$1,000	$1,000
	Plant ownership		
	Basic plant $ 7,692/month		
	Booster $ 2,475/month (1 @ $7,500 × 33%)		
	$10,167/month divided by 30.42	$ 334	$ 334
	Subsistence 6 men @ $25 per day		$ 150
	Cost per day	$3,452	$3,602
2.	Prepare pipeline for transfer		
	6 men @ 8 hr/day @ $37.88 per hour	$1,818	$1,818
	Supplies and small tools	$ 300	$ 300
	Pipeline ownership		
	$11,250/month divided by 30.42 days/month × 50% =	$ 185	$ 185
	Subsistence 6 men @ $25 per day		$ 150
	Cost per day	$2,303	$2,453
3.	Transfer plant		
	6 men/shift (1 12-hr shift/day) @ $37.88/hr	$2,727	$2,727
	Plant ownership	$ 334	$ 334
	Pipeline ownership	$ 185	$ 185
	Plant costs ($16,593 month) (operating cost minus payroll) divided by 30.42 days/month × 50%	$ 273	$ 273
	Subsistence 12 men @ $25 per day	$ 300	$ 300

Table C2

CDF Option B Costs

Activity	Quantity	Unit Cost	Total Cost
Construct CDF 1			$ 2,947,800
Fill CDF 1			
Hydraulically placed	165,465 cu yd	$ 9.70	$ 1,605,011
Mechanically placed	30,000 cu yd	$ 5.85	$ 175,500
Construct CDF 3			$ 5,060,200
Fill CDF 3			
Hydraulically placed	96,780 cu yd	$ 9.70	$ 938,766
Construct CDF 1B			$ 4,289,600
Fill CDF 1B			
Hydraulically placed	38,705 cu yd	$ 9.70	$ 375,439
Construct CDF 12			$ 2,380,100
Fill CDF 12			
Hydraulically placed	183,310 cu yd	$ 9.70	$ 1,778,107
Silt curtain/oil boom	200 ft	$ 40.00	$ 8,000
Cap CDFs			
Hydraulically placed	202,400 cu yd	$ 9.70	$ 1,963,280
Subtotal			$21,521,800
Contingencies (20%)			$ 4,304,360
Engineering & design			$ 420,000
Construction admin. & inspection			$ 1,807,831
Total first cost			$28,053,991
Annual operation & maintenance cost			$ 87,000

Note: Refer to Table C1.

Table C3

CDF Option C Costs

Activity	Quantity	Unit Cost	Total Cost
Construct CDF 12 (lined)			$ 4,532,900
Fill CDF 12	232,870 cu yd	$11.80	$ 2,747,866
Construct CDF 6 (lined)			$ 1,925,600
Fill CDF 6	71,715 cu yd	$11.80	$ 846,237
Construct CDF 1			$ 2,947,800
Fill CDF 1	161,275 cu yd	$11.80	$ 1,903,045
Mechanically placed	30,500 cu yd	$ 5.85	$ 178,425
Construct CDF 3			$ 5,060,200
Fill CDF 3	77,615 cu yd	$11.80	$ 915,857
Silt curtain/oil boom	200 ft	$40.00	$ 8,000
Cap CDFs			
Hydraulically placed	202,100 cu yd	$11.80	$ 2,384,780
Subtotal			$23,450,710
Contingencies (20%)			$ 4,690,142
Engineering & design			$ 420,000
Construction admin. & inspection			$ 1,969,860
Total first cost			$30,530,712
Annual operation & maintenance cost			$ 57,000

Notes:

Refer to notes 1, 2 and 3 of Table C1.

The distance from dredging areas to disposal sites requires three booster pumps.

Table C4

CDF Option D Costs

Activity	Quantity	Unit Cost	Total Cost
Construct CDF 12 (lined)			$ 4,532,900
Fill CDF 12	231,960 cu yd	$12.10	$ 2,803,449
Construct CDF 6 (lined)			$ 1,925,600
Fill CDF 6	69,445 cu yd	$12.10	$ 840,285
Construct CDF 1 (lined)			$ 9,519,700
Fill CDF 1	152,780 cu yd	$12.10	$ 1,848,638
Mechanically placed	42,000 cu yd	$ 5.85	$ 245,700
Construct CDF 3 (lined)			$ 6,369,500
Construct CDF 1B (lined)			$ 6,278,600
Fill CDF 3	86,920 cu yd	$12.10	$ 1,051,732
Fill CDF 1B	41,945 cu yd	$12.10	$ 507,535
Mechanically placed	8,000 cu yd	$ 5.85	$ 46,800
Silt curtain/oil boom	200 ft	$40.00	$ 8,000
Cap CDFs - hydraulically placed	231,100 cu yd	$12.10	$ 2,796,310
Subtotal			$38,774,749
Contingencies (20%)			$ 7,754,950
Engineering & design			$ 600,000
Construction admin. & inspection			$ 3,257,079
Total first cost			$50,386,778
Annual operation & maintenance cost			$ 87,000

Note: Refer to Table C1.

Table C5

CAD Option A Costs

Activity	Quantity	Unit Cost	Total Cost
Construct CDF 1			$ 2,947,800
Construct CDF 3			$ 5,060,200
Construct CDF 1A			$ 2,998,100
Construct CDF 12 (temp.)			$ 1,616,500
Dredging	1,177,375 cu yd	$ 9.60	$11,302,800
Shoreline excavation	26,100 cu yd	$ 5.85	$ 152,685
Silt curtain/oil boom	700 ft	$40.00	$ 28,000
Remove temporary CDF	167,500 cu yd	$ 6.35	$ 1,063,625
Restore temporary CDF area	107,000 sq yd	$ 3.00	$ 321,000
Subtotal			$25,490,710
Contingencies (20%)			$ 5,098,142
Engineering & design			$ 470,000
Construction admin. & inspection			$ 2,141,220
Total first cost			$33,200,072
Annual operation & maintenance cost			$ 105,000

Notes:

1. Refer to Table C1.

2. Operation and maintenance costs also include hydrographic surveys of CAD area and periodic sampling of CAD cells.

3. The temporary CDF area is restored with topsoil and seeded.

Table C6

CAD Option B Costs

Activity	Quantity	Unit Cost	Total Cost
Construct CDF 1			$ 2,947,800
Construct CDF 1A			$ 2,998,100
Construct CDF 6 (temp.)			$ 690,800
Construct CDF 12 (temp.)			$ 1,616,500
Dredging	1,696,270 cu yd	$ 9.65	$16,369,005
Shoreline excavation	34,500 cu yd	$ 5.85	$ 201,825
Silt curtain/oil boom	700 ft	$40.00	$ 28,000
Remove temporary CDFs	234,200 cu yd	$ 6.35	$ 1,487,170
Restore temporary CDF areas	150,000 sq yd	$ 3.00	$ 450,000
Subtotal			$26,789,200
Contingencies (20%)			$ 5,357,840
Engineering & design			$ 400,000
Construction admin. & inspection			$ 2,250,293
Total first cost			$34,797,333
Annual operation & maintenance cost			$ 82,000

Notes: Refer to Table C1.

Table C7

Construction Costs for Site 1 Unlined

Activity	Quantity	Unit Cost	Total Cost
Granular fill			
Inwater - stage 1	26,400 cu yd	$19.00	$ 501,600
Inwater - stage 2	29,555 cu yd	$19.00	$ 561,500
Land dike	7,100 cu yd	$ 6.35	$ 45,100
Geotextile	23,200 sq yd	$22.50	$ 522,000
Stone protection	2,800 cu yd	$50.50	$ 141,400
Sheetpile (secondary cell)	6,000 lin ft	$33.50	$ 201,000
Fence	2,400 lin ft	$23.50	$ 56,400
Walkway and weir	1		$ 28,500
Outlet structure	1		$ 14,500
Topsoil & seed (dike)	8,000 sq yd	$ 3.00	$ 24,000
Geotechnical monitoring	1		$ 50,000
Traffic control	55,700 cu yd	$ 0.70	$ 39,000
Capping material	34,300 cu yd	$ 6.35	$ 217,800
Topsoil & seed (cap)	103,000 sq yd	$ 3.00	$ 309,000
Geomembrane liner (cap)	103,000 sq yd	$ 2.00	$ 206,000
Silt curtain	1,200 lin ft	$25.00	$ 30,000
Total cost			$ 2,947,800

Table C8

Construction Costs for Site 1 Lined

Item	Quantity	Unit Price	Total
Cost			
Shoreline excavation	14,300 cu yd	$ 5.00	$ 71,500
Fill site (clean dredged material)	275,000 cu yd	$ 3.50	$ 962,500
Geotextile	36,000 sq yd	$22.50	$ 810,000
Granular fill			
Inwater - stage 2	46,500 cu yd	$19.00	$ 883,500
Inwater - stage 3	12,300 cu yd	$ 6.35	$ 78,100
Land dike	49,900 cu yd	$ 6.35	$ 316,900
Sheet-pile wall	78,000 lin ft	$33.50	$ 2,613,000
Liner			
Low-permeability material	34,300 cu yd	$ 8.00	$ 274,400
Sand	68,600 cu yd	$ 8.00	$ 548,800
Geomembrane liner	206,000 sq yd	$ 2.00	$ 412,000
Geotextile	103,000 sq yd	$ 2.50	$ 257,500
Leachate collection	171,000 lin ft	$ 4.25	$ 726,800
Stone protection	2,800 cu yd	$50.50	$ 141,400
Sheet-pile (secondary cell)	12,000 lin ft	$33.50	$ 402,000
Fence	2,400 lin ft	$23.50	$ 56,400
Walkway and weir	1		$ 28,500
Outlet structure	1		$ 14,500
Topsoil & seed (dike)	11,000 sq yd	$ 3.00	$ 33,000
Geotechnical monitoring	1		$ 50,000
Traffic control	108,700 cu yd	$ 0.70	$ 76,100
Capping material	34,300 cu yd	$ 6.35	$ 217,800
Geomembrane liner (cap)	103,000 sq yd	$ 2.00	$ 206,000
Topsoil & seed (cap)	103,000 sq yd	$ 3.00	$ 309,000
Silt curtain	1,200 lin ft	$25.00	$ 30,000
Total cost			$ 9,519,700

Table C9

Construction Costs for Site 1A Unlined

Item	Quantity	Unit Price	Total Cost
Granular fill			
Inwater - stage 1	26,400 cu yd	$19.00	$ 501,600
Inwater - stage 2	29,555 cu yd	$19.00	$ 561,500
Land dike	9,000 cu yd	$ 6.35	$ 57,200
Geotextile	23,200 sq yd	$22.50	$ 522,000
Stone protection	2,400 cu yd	$50.50	$ 121,200
Sheet pile (secondary cell)	5,400 lin ft	$33.50	$ 180,900
Fence	1,000 lin ft	$23.50	$ 23,500
Walkway and weir	1		$ 28,500
Outlet structure	1		$ 14,500
Topsoil & seed (dike)	2,200 sq yd	$ 3.00	$ 6,600
Geotechnical monitoring	1		$ 50,000
Traffic control	57,200 cu yd	$ 0.70	$ 40,000
Capping material	6,150 cu yd	$ 6.35	$ 39,100
Topsoil & seed (cap)	18,400 sq yd	$ 3.00	$ 55,200
Membrane liner (cap)	18,400 sq yd	$ 2.00	$ 36,800
Sheet-pile wall	22,000 lin ft	$33.50	$ 737,000
Silt curtain	900 lin ft	$25.00	$ 22,500
Total cost			$ 2,998,100

Table C10

Construction costs for Site 1B Unlined

Item	Quantity	Unit Price	Total Cost
Granular fill			
Inwater - stage 1	50,000 cu yd	$19.00	$ 950,000
Inwater - stage 2	56,000 cu yd	$19.00	$ 1,064,000
Land dike	25,200 cu yd	$ 6.35	$ 160,000
Geotextile	44,000 sq yd	$22.50	$ 990,000
Stone protection	4,500 cu yd	$50.50	$ 227,300
Sheet pile (secondary cell)	9,000 lin ft	$33.50	$ 301,500
Fence	2,300 lin ft	$23.50	$ 54,100
Walkway and weir	1		$ 28,500
Outlet structure	1		$ 14,500
Topsoil & seed (dike)	4,500 sq yd	$ 3.00	$ 13,500
Geotechnical monitoring	1		$ 50,000
Traffic control	116,500 cu yd	$ 0.70	$ 81,600
Capping material	14,500 cu yd	$ 6.35	$ 92,100
Topsoil & seed (cap)	44,000 sq yd	$ 3.00	$ 132,000
Membrane liner (cap)	44,000 sq yd	$ 2.00	$ 88,000
Silt curtain	1,700 lin ft	$25.00	$ 42,500
Total cost			$ 4,289,600

Table C11

Construction Costs for Site 1B Lined

Item	Quantity	Unit Price	Total Cost
Shoreline excavation	18,500 cu yd	$ 5.00	$ 92,500
Fill site (clean dredged material)	87,500 cu yd	$ 6.60	$ 577,500
Geotextile	68,000 sq yd	$22.50	$ 1,530,000
Granular fill			
Inwater - stage 2	88,000 cu yd	$19.00	$ 1,672,000
Inwater - stage 3	23,300 cu yd	$ 6.35	$ 148,000
Land dike	62,000 cu yd	$ 6.35	$ 393,700
Liner			
Low-permeability material	14,600 cu yd	$ 8.00	$ 116,800
Geomembrane liner	88,000 sq yd	$ 2.00	$ 176,000
Geotextile	44,000 sq yd	$ 2.50	$ 110,000
Leachate collection	72,000 lin ft	$ 4.25	$ 306,000
Sand	29,200 cu yd	$ 8.00	$ 233,600
Stone protection	4,500 cu yd	$50.50	$ 227,300
Sheet pile (secondary cell)	1,800 lin ft	$33.50	$ 60,300
Fence	2,300 lin ft	$23.50	$ 54,100
Walkway and weir	1		$ 28,500
Outlet structure	1		$ 14,500
Topsoil & seed (dike)	5,500 sq yd	$ 3.00	$ 16,500
Geotechnical monitoring	1		$ 50,000
Traffic control	166,700 cu yd	$ 0.70	$ 116,700
Capping material	14,500 cu yd	$ 6.35	$ 92,100
Topsoil & seed (cap)	44,000 sq yd	$ 3.00	$ 132,000
Membrane liner (cap)	44,000 sq yd	$ 2.00	$ 88,000
Silt curtain	1,700 lin ft	$25.00	$ 42,500
Total cost			$ 6,278,600

Table C12

Construction Costs for Site 3 Unlined

Item	Quantity	Unit Price	Total Cost
Granular fill			
Inwater - stage 1	50,000 cu yd	$19.00	$ 950,000
Inwater - stage 2	56,000 cu yd	$19.00	$ 1,064,000
Land dike	7,100 cu yd	$ 6.35	$ 45,100
Geotextile	44,000 sq yd	$22.50	$ 990,000
Stone protection	4,500 cu yd	$50.50	$ 227,300
Sheet pile (secondary cell)	9,000 lin ft	$33.50	$ 301,500
Fence	1,700 lin ft	$23.50	$ 40,000
Walkway and weir	1		$ 28,500
Outlet structure	1		$ 14,500
Topsoil & seed (dike)	2,800 sq yd	$ 3.00	$ 8,400
Geotechnical monitoring	1		$ 50,000
Traffic control	98,400 cu yd	$ 0.70	$ 68,900
Capping material	16,400 cu yd	$ 6.35	$ 104,100
Topsoil & seed (cap)	49,200 sq yd	$ 3.00	$ 147,600
Membrane liner (cap)	49,200 sq yd	$ 2.00	$ 98,400
Sheet-pile wall	26,400 lin ft	$33.50	$ 884,400
Silt curtain	1,500 lin ft	$25.00	$ 37,500
Total cost			$ 5,060,200

Table C13

Construction Costs for Site 3 Lined

Item	Quantity	Unit Price	Total Cost
Shoreline excavation	6,300 cu yd	$ 5.00	$ 31,500
Fill site (clean dredged material)	98,400 cu yd	$ 4.30	$ 423,100
Geotextile	68,000 sq yd	$22.50	$ 1,530,000
Granular fill			
Inwater - stage 2	88,000 cu yd	$19.00	$ 1,672,000
Inwater - stage 3	23,300 cu yd	$ 6.35	$ 148,000
Land dike	34,200 cu yd	$ 6.35	$ 217,200
Sheet pile (secondary cell)	18,000 lin ft	$33.50	$ 603,000
Liner			
Low-permeability material	16,400 cu yd	$ 8.00	$ 131,200
Sand	32,800 cu yd	$ 8.00	$ 262,400
Geomembrane liner	98,400 sq yd	$ 2.00	$ 196,800
Geotextile	49,200 sq yd	$ 2.50	$ 123,000
Leachate collection	72,000 lin ft	$ 4.25	$ 306,000
Stone protection	4,500 cu yd	$50.50	$ 227,300
Fence	1,700 lin ft	$23.50	$ 40,000
Walkway and weir	1		$ 28,500
Outlet structure	1		$ 14,500
Topsoil & seed (dike)	2,800 sq yd	$ 3.00	$ 8,400
Geotechnical monitoring	1		$ 50,000
Traffic control	149,900 cu yd	$ 0.70	$ 104,900
Capping material	16,400 cu yd	$ 6.35	$ 104,100
Topsoil & seed (cap)	49,200 sq yd	$ 3.00	$ 147,600
Membrane liner (cap)	49,200 sq yd	$ 2.00	$ 98,400
Sheet-pile wall	44,000 lin ft	$33.50	$ 1,474,000
Silt curtain	1,500 lin ft	$25.00	$ 37,500
Total cost			$ 6,369,500

Table C14

Construction Costs for Site 6 Unlined/Temporary

Item	Quantity	Unit Price	Total Cost
Granular fill	66,700 cu yd	$ 6.35	$ 423,500
Fence	2,600 lin ft	$23.50	$ 61,100
Walkway and weir	1		$ 28,500
Outlet structure (to water)	1		$ 30,000
Topsoil & seed (dike)	7,000 sq yd	$ 3.00	$ 21,000
Traffic control	109,600 cu yd	$ 0.70	$ 76,700
Clearing	1		$ 50,000
Total cost			$ 690,800

Table C15

Construction Costs for Site 6 Lined

Item	Quantity	Unit Price	Total Cost
Granular fill	66,700 cu yd	$ 6.35	$ 423,500
Liner			
Low-permeability material	14,300 cu yd	$ 8.00	$ 114,400
Sand	28,600 cu yd	$ 8.00	$ 228,800
Geomembrane liner	86,000 sq yd	$ 2.00	$ 172,000
Geotextile	43,000 sq yd	$ 2.50	$ 107,500
Leachate collection	72,000 lin ft	$ 4.25	$ 306,000
Fence	2,600 lin ft	$23.50	$ 61,100
Walkway and weir	1		$ 28,500
Outlet structure (to water)	1		$ 30,000
Topsoil & seed (dike)	7,000 sq yd	$ 3.00	$ 21,000
Traffic control	109,600 cu yd	$ 0.70	$ 76,700
Capping material	14,350 cu yd	$ 6.35	$ 91,100
Topsoil & seed (cap)	43,000 sq yd	$ 3.00	$ 129,000
Membrane liner (cap)	43,000 sq yd	$ 2.00	$ 86,000
Clearing	1		$ 50,000
Total cost			$ 1,925,600

Table C16

Construction Costs for Site 12 Unlined

Item	Quantity	Unit Price	Total Cost
Granular fill	167,500 cu yd	$ 6.35	$ 1,063,600
Fence	6,400 lin ft	$23.50	$ 150,400
Walkway and weir	1		$ 28,500
Outlet structure (to water)	1		$ 30,000
Topsoil & seed (dike)	19,000 sq yd	$ 3.00	$ 57,000
Traffic control	267,100 cu yd	$ 0.70	$ 187,000
Capping material	36,000 cu yd	$ 6.35	$ 228,600
Topsoil & seed (cap)	107,000 sq yd	$ 3.00	$ 321,000
Membrane liner (cap)	107,000 sq yd	$ 2.00	$ 214,000
Demolition & clearing	1		$ 100,000
Total cost			$ 2,380,100

Table C17

Construction Costs for Site 12 Lined

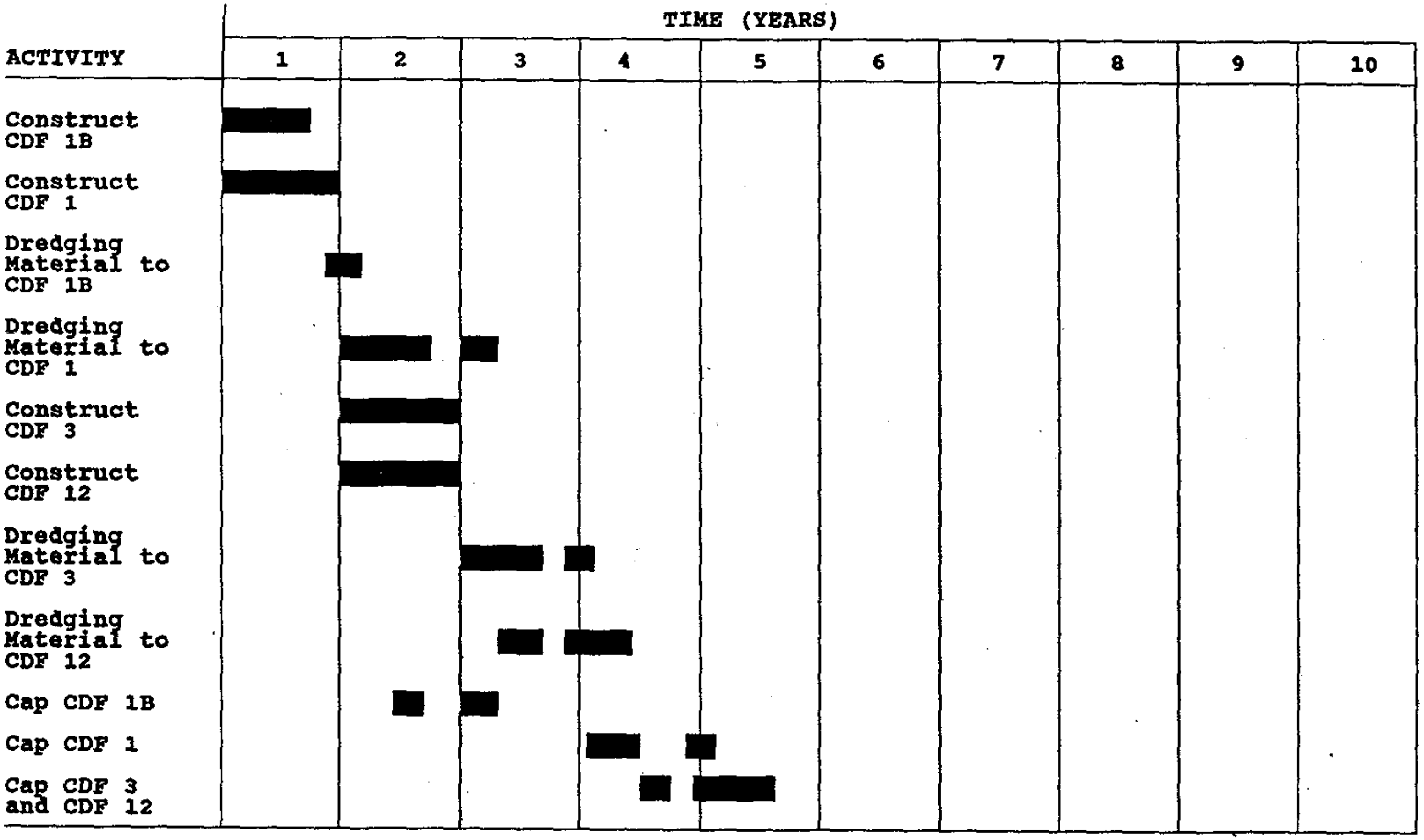
Item	Quantity	Unit Price	Total Cost
Granular fill	167,500 cu yd	$ 6.35	$ 1,063,600
Liner			
Low-permeability material	33,200 cu yd	$ 8.00	$ 265,600
Sand	66,400 cu yd	$ 8.00	$ 531,200
Geomembrane liner	200,000 sq yd	$ 2.00	$ 400,000
Geotextile	107,000 sq yd	$ 2.50	$ 267,500
Leachate collection	162,000 lin ft	$ 4.25	$ 688,500
Fence	6,400 lin ft	$23.50	$ 150,400
Walkway and weir	1		$ 28,500
Outlet structure (to water)	1		$ 30,000
Topsoil & seed (dike)	19,000 sq yd	$ 3.00	$ 57,000
Traffic control	267,100 cu yd	$ 0.70	$ 187,000
Capping material	36,000 cu yd	$ 6.35	$ 228,600
Topsoil & seed (cap)	107,000 sq yd	$ 3.00	$ 321,000
Membrane liner (cap)	107,000 sq yd	$ 2.00	$ 214,000
Demolition & clearing	1		$ 100,000
Total cost			$ 4,532,900

Table C18

Additional Cost for CDF Effluent Treatment and Operation and Maintenance

Item	Chemical Clarification	Filtration	Carbon Adsorption	Leachate Treatment	Site Manage-ment	Monitoring	Dike Main-tenance
Capital cost	96	2,557	2,876	589	N/A	N/A	N/A
Annual O&M cost - during operations (3-10 years)	87	192	449	41	N/A	250	N/A
Annual O&M cost - postoperations (approx. 5 years)	N/A	N/A	N/A	41	10	100	N/A
Annual O&M cost - long term (10-30 years)	N/A	N/A	N/A	41	10	50	870*

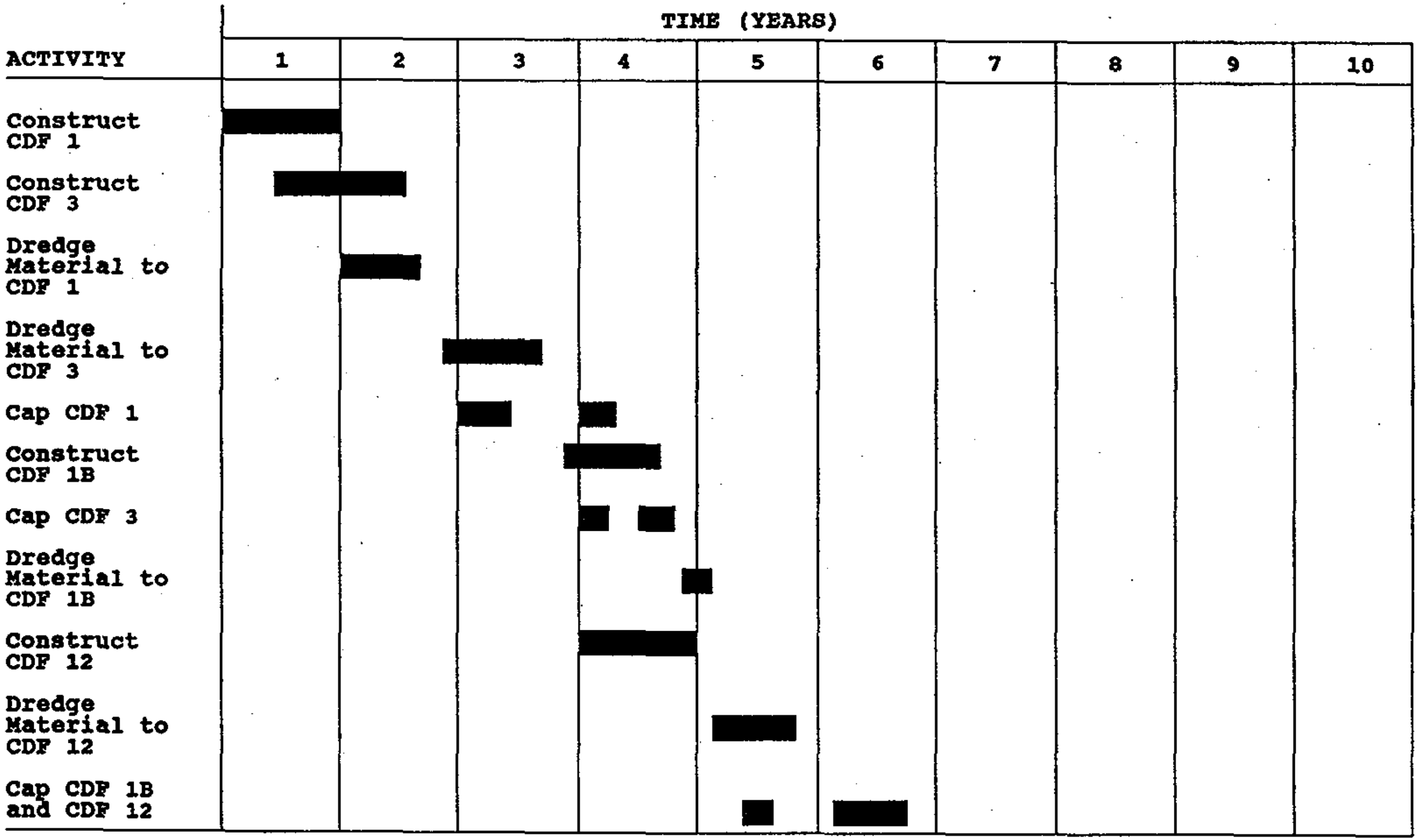
Note: All costs expressed in thousands of dollars.
* Dike maintenance cost incurred once each 10 years.



Notes: CDF ALTERNATIVE A: Construction sequence

1. All CDFs unlined
2. Construction season begins on 1 April
3. Only one dredge operating in contaminated sediment at one time
4. Two dredges onsite at all times
5. Production rate per day - 800 cu yd
6. 25 working days per month
7. No dredging work Dec 1 - March 1
8. Capping performed in two stages: Dredged material and fill trucked to site
9. Three-month consolidation period required prior to placement of cap

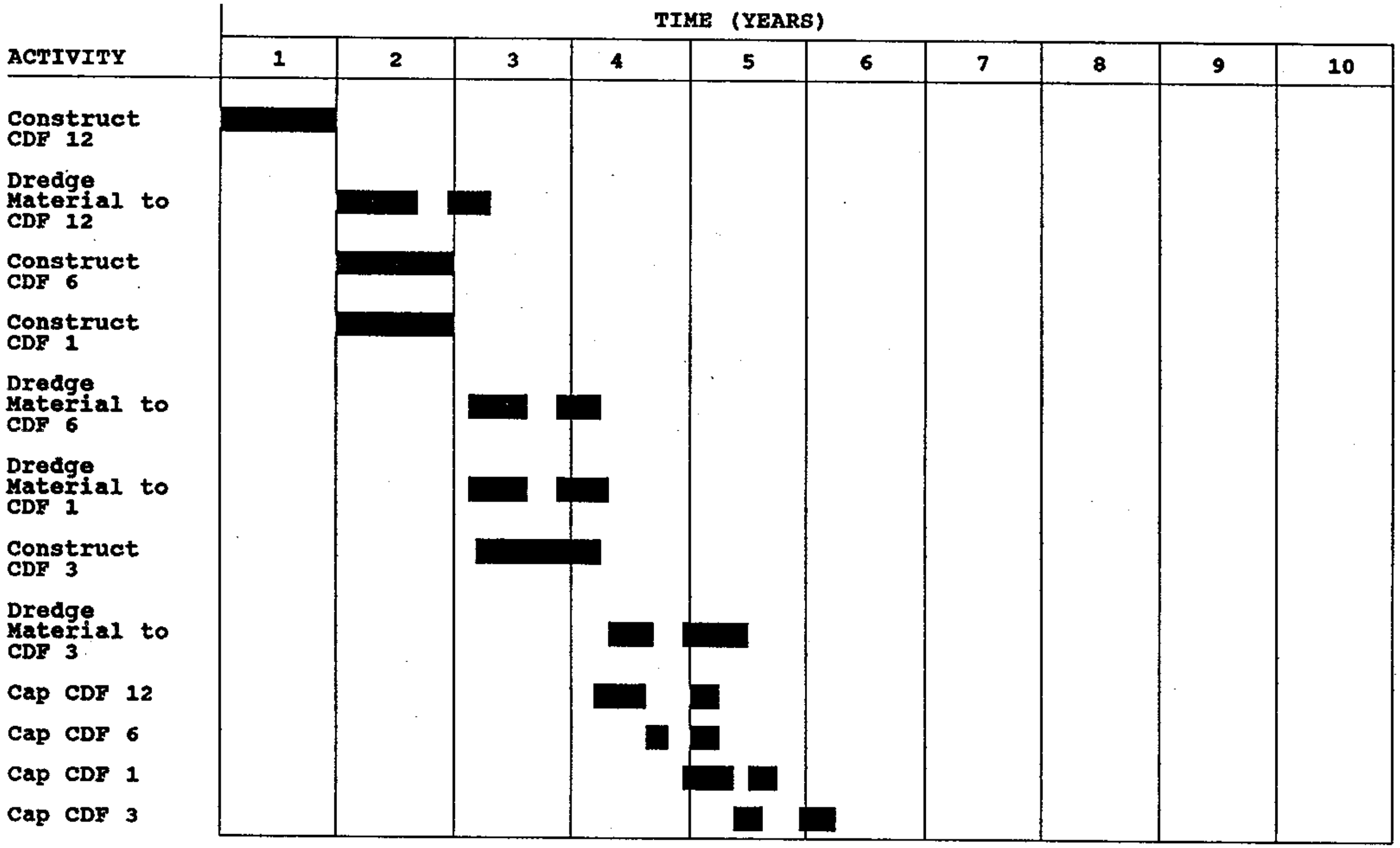
Figure C1. Construction sequence for CDF Alternative A



Notes: CDF ALTERNATIVE B: Construction sequence

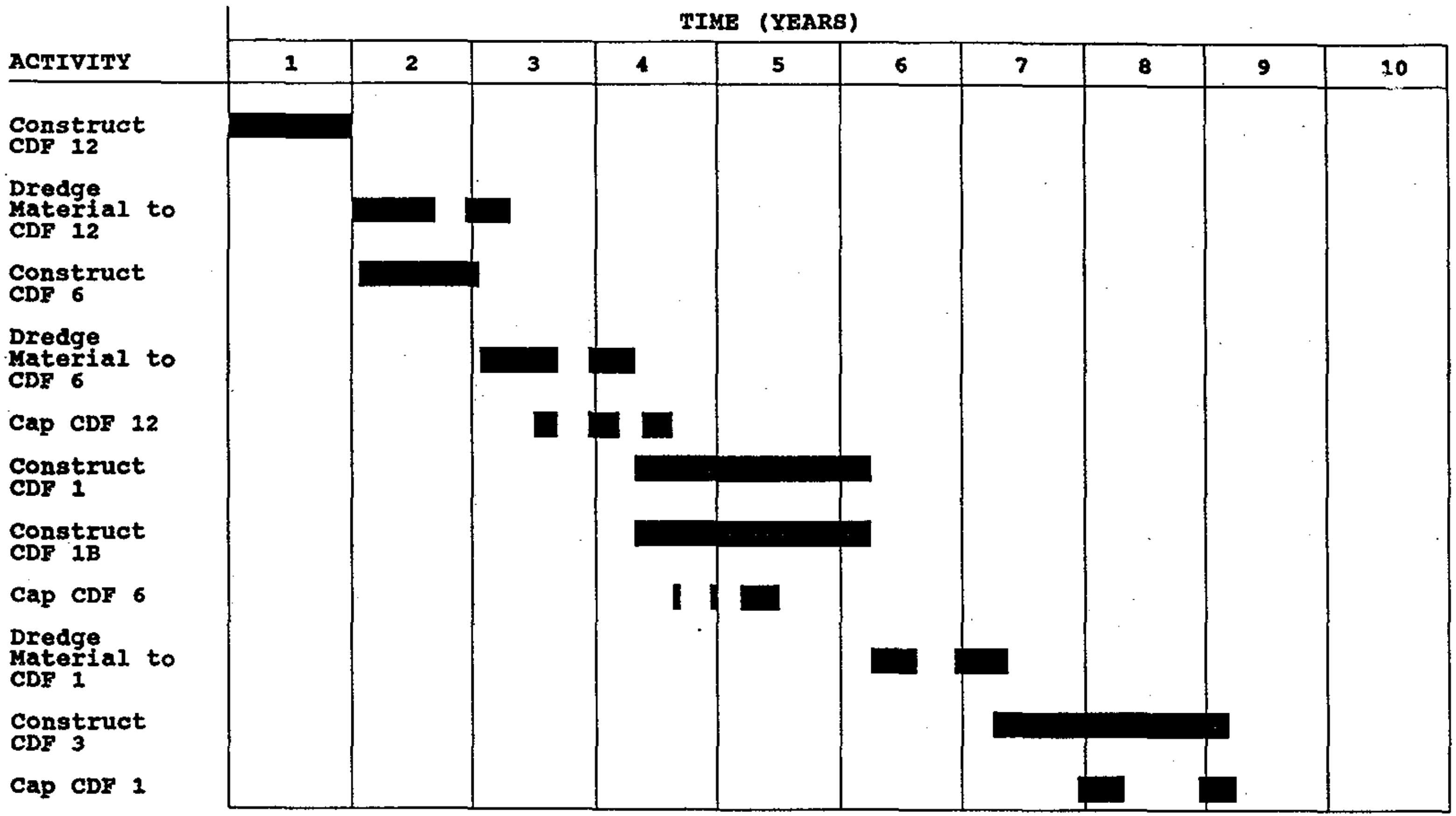
1. **All *CDFs* unlined**
2. **Contaminated material removed from area of CDF 1B**

Figure C2. Construction sequence for CDF Alternative B



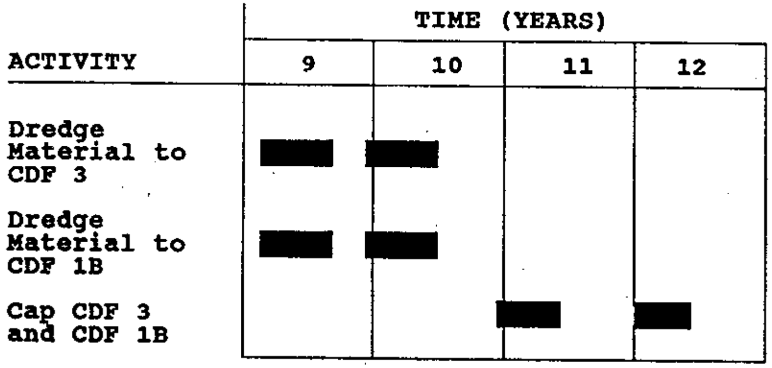
Notes: CDF ALTERNATIVE C: Construction sequence
1. CDFs 12 and 6 lined

Figure C3. Construction sequence for CDF Alternative C



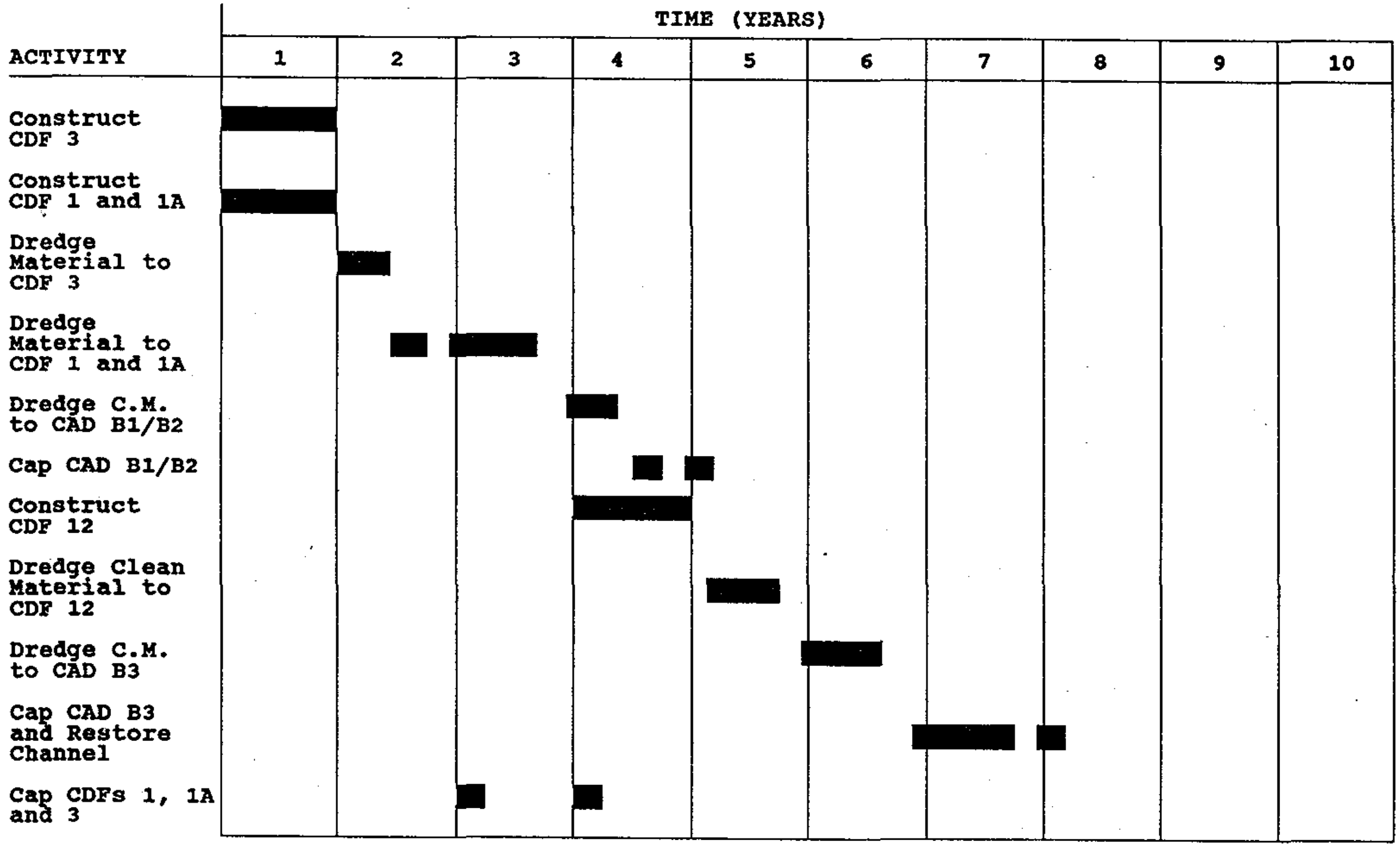
Notes: CDF ALTERNATIVE D: Construction sequence
1. All CDFs are lined

Figure C4. Construction sequence for CDF Alternative D (Continued)



Notes: CDF ALTERNATIVE D: Construction sequence (continued)
1. All CDFs are lined

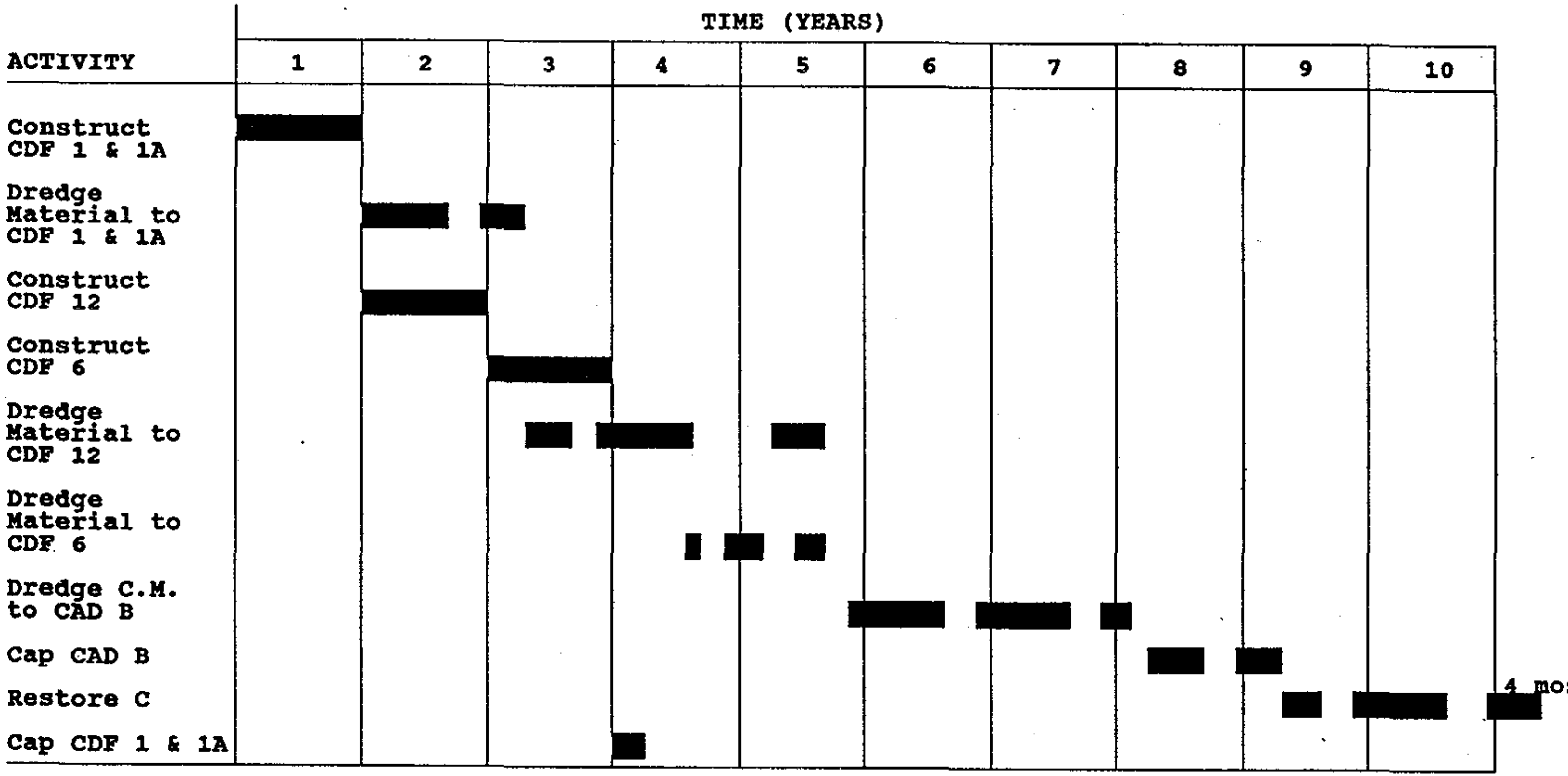
Figure C4. (Concluded)



Notes: CAD OPTION A: Construction sequence

1. CDFs unlined
2. CDF 12 contains only clean material and is temporary
3. C.M. = contaminated material
4. Cap for CDFs 1, 1A, and 3 consists of a membrane liner, 2 ft of fill from a land source, topsoil, and seed

Figure C5. Construction sequence for CAD option A



Notes: CAD OPTION B: Construction Sequence

1. CDFs unlined
2. CDF 12 and 6 contain only clean material and are temporary
3. It is assumed that the material being placed in CDFs 12 and 6 is coarse grained and can be rehandled to provide an additional 130,000+ cu yd of capacity. Construction of CDF 5 will not be necessary.
4. Cap for CDF 1 and 1A consists of membrane liner covered with 2 ft of fill from a land source and topsoil and seed.

Figure C6. Construction sequence for CAD option B

APPENDIX D: ESTIMATED CONTAMINANT RELEASE FROM DREDGING AND DREDGED MATERIAL DISPOSAL

Introduction

Background

1. Sediment to be dredged from the New Bedford Harbor Superfund Project is contaminated with polychlorinated biphenyls (PCBs) and heavy metals. Remedial alternatives for removing and disposing of this sediment will increase the release of these contaminants above existing background conditions for the period of time required to remove the contaminated sediment from the estuary. Impacts of these relatively short-term releases must be weighed against the benefits of removing the bulk of the contaminants from the estuary to improve water quality, aquatic resources, and public health for the long term.

2. Various project activities may release or increase the potential for mobility of contaminants to the environment. These activities include the confined disposal facility (CDF) dike construction for in-water sites, the dredging operation, effluent from the CDF during filling, surface runoff from the filled and capped CDF, leachate from the CDF, and the contained aquatic disposal (CAD) filling/capping operation. The primary migration pathways for transport of contaminants from these operations to the environment are surface water (for dike construction, dredging, CAD filling, and effluent from CDF) and ground water (for leachate). Other pathways are air and biological uptake by organisms in the CAD and CDF site.

Scope

3. This appendix presents estimates of the magnitude of contaminants, specifically PCBs and selected heavy metals, that may be released by the dredging and disposal alternatives being addressed by this Engineering Feasibility Study (EFS). The estimates are based on the data developed by EFS Tasks 4 and 6. Task 4 predicted sediment resuspension rates during dredging, modeled sediment transport and migration for the estuary, and evaluated existing PCB fluxes from the estuary. Testing protocols performed under Task 6 provided data for heavy metal and PCB concentrations for dissolved and particle-associated transport mechanisms from dredging and disposal operations

to surface and ground water. The detailed results of Tasks 4 and 6 are presented in Reports 2-10 of the series.

Technical approach

4. Most of the Management Strategy (Francingues et al. 1985*) testing protocols yield a qualitative assessment of chemical quality for CDF effluent, runoff, and leachate and for open-water disposal. Quantification of contaminant releases from CDF effluent is straightforward. However, techniques for quantifying CDF leachate releases and for estimating releases from the dredging operation and from the CAD operation are not well developed or field proven. Results from the New Bedford Superfund Pilot Study (Otis and Andreliunas 1987) will allow refinement of these estimates by verifying bench-scale results and accounting for field conditions, prototype dredging activities, and site-specific conditions at the New Bedford Harbor Superfund Site.

5. The releases calculated herein are intended to be worst-case estimates. Contaminant concentrations during active dredging and disposal operations are based on testing of the EFS estuary composite sample (see Report 2), which has greater contaminant concentrations in the bulk sediment than the average bulk sediment that will be dredged in the estuary. In general, application of laboratory and field data and selection of values from the literature are conservative with respect to protection of the environment during dredging and disposal.

6. Scenarios for dredging and disposal alternatives involve dredging between the Wood Street and Coggeshall Street bridges, a number of different CDFs, and a combination of CDFs and CAD cells. This appendix will initially discuss contaminant releases in a general sense, followed by contaminant release estimates for the components, i.e., dredging, CDF effluent, CDF surface runoff, CDF leachate, and CAD filling. Finally, releases from the components will be combined into short-term releases (5 to 12 years of dredging operations) and long-term releases, i.e., after completion of dredging. Disturbance of contaminated sediment at the dredgehead, displacement of contaminated sediment during construction of in-water CDFs, contaminant release during and after filling the CDF with dredged material, and contaminant release during and after placing and capping dredged material in the CAD cell

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* See References at the end of the main text.

present avenues for release of contaminants to the environment. These operations and the primary environmental pathways potentially affected by these operations are discussed in the following section.

Description of Releases from Dredging and Disposal Components

Dredging

7. In a hydraulic dredging operation, large quantities of water mix with the sediment to form a slurry as the dredge works its suction pipe (usually equipped with a cutter, auger, or other dredgehead) into the sediment and pumps dredged material through a pipeline to the disposal facility. Operation of the dredge in the contaminated sediment will resuspend some sediment with attached contaminants and potentially release dissolved contaminants into the water column and affect surface water quality. Sediment resuspension by various types of dredging equipment is discussed in Report 10. The quantity of sediment resuspended will be minimized by selection of equipment that has been demonstrated to produce a reduced rate of sediment resuspension and by operation of the selected equipment in a manner to minimize sediment resuspension.

8. The heavier resuspended sediment particles from the dredging operation will settle on the bottom near the dredge. The finer sediment particles will disperse into the water column. Sediment concentration in the water column will decrease with distance downcurrent from the dredge. Contaminants attached to the suspended sediment will be transported with the sediment, and soluble contaminants will be transported with water movement. However, some of the soluble contaminants are expected to become reattached (adsorbed) to suspended sediment and will then be transported in the same fashion as suspended sediment.

Dike construction

9. Construction of in-water dikes where required for shoreline CDFs will involve hauling clean fill material from offsite and carefully placing this material into the estuary as the dike is built from the shore. Earthmoving equipment will shape and compact the material for the dikes. The filling operation will impact an area the length and base line width of the

dike (approximately 150 ft*). The sediment underneath the dikes, which is also contaminated with PCBs, will be disturbed, compacted, and partially displaced by the dike construction operation. Silt screens used during dike construction for the Pilot Study were effective in containing the suspended sediment that was produced. Compaction of the contaminated sediment beneath the dike will squeeze pore water through and out of the sediment. This pore water contains soluble contaminants in high concentrations compared with water quality criteria. However, the volume of pore water is very small compared with the volume of the estuary and is released to surface water at a slow rate. The effect of this release will be small compared with other components of the dredging and disposal operation.

CDF during dredging

10. The CDF provides storage for the dredged material and will provide adequate volume to separate solids from liquid by gravity settling. After solids in the dredged material slurry settle in the disposal facility, excess water or supernatant is released from the disposal facility. This excess water that has been in contact with the sediment during the dredging process can be expected to contain dissolved and particulate-associated contaminants from the sediment. The CDFs proposed in this study will include provisions for the addition of polymers at the overflow from the primary cell of the CDF. These polymers will promote flocculation of fine particulates that may be removed by settling in the secondary cell of the CDF. Final effluent discharged from the CDF during the filling operation will contain nonsettleable particulates with associated contaminants as well as dissolved contaminants. Without additional effluent treatment, most of these materials can be expected to be transported away from the project area.

11. A second potential pathway of concern during filling of the CDF is volatilization of contaminants into the air. This release mechanism will be minimized by submerging the influent pipe below water level as slurry is pumped into the CDF and by keeping the contaminated sediment covered with water and saturated until the CDF is capped with clean material. Thibodeaux (in preparation) showed that the loss of PCBs from CDFs during filling is a significant pathway. Thibodeaux's calculations for the Pilot Study CDF

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5 of the main text.

produced an estimate of 754 mg/hr PCB volatilization from the 60,000-sq ft pilot CDF. Using the same assumptions for PCB emission data, suspended sediment concentrations, and CDF configuration, and increasing the emission rate for the 2,700,000 sq ft of CDF area for the options considered in this study, a PCB emission rate on the order of 0.8 kg/day is estimated.

CDF after filling

12. The various pathways that may be affected by contaminated sediment in the CDF once the facility is filled are illustrated in Figures 7 and 8 of the main text. These pathways include surface runoff, biological uptake, volatilization, seepage, and leachate. Capping the CDF with clean dredged material will minimize the magnitude of the contaminant releases via the first three pathways mentioned. The pathway of most concern for the completed CDF is loss of leachate from the contaminated sediment through the bottom of the facility or seepage through the dike adjacent to the shore.

13. Loss of leachate from the CDF depends on hydraulic gradients and characteristics of the dike and foundation materials. The controlling hydraulic gradient for a free-draining foundation is directed downward in proportion to the static head produced by the height of saturated dredged material above the bottom of the CDF or above the water level on the outside of the dike, whichever is higher. Free drainage of pore water from the dredged material will slowly dissipate this head, but will force leachate through the bottom of the site.

14. The low permeability of the dredged material (10^{-6} to 10^{-7} cm/sec) limits the rate of infiltration of water downward from the surface of the CDF. Once the CDF is filled and capped, drainage will be provided to prevent ponding of water on the surface, and most rainwater will run off. Evaporation, and later evapotranspiration if the site becomes vegetated, will reduce the volume of rainwater and snowmelt transmitted downward, resulting in a layer of unsaturated dredged material near the surface of the CDF. Therefore, the primary contributor to leachate or seepage volume is the pore water associated with the dredged material placed in the site.

15. Modifying the bottom of the CDF to impede leachate flow or breaking the hydraulic gradient by collecting leachate at the bottom of the CDF will reduce leachate percolation from the bottom of the site. However, lining the CDF(s) for a remedial action at New Bedford will increase the overall cleanup cost. Lining large in-water CDFs also presents construction requirements that

have not been fully demonstrated in the industry, and long-term reliability of a liner is questionable.

16. Clean material used to cover the CDF will minimize losses through volatilization, bioturbation, or surface runoff. Thibodeaux (in preparation) showed that exposed contaminated sediment produced a much higher (3 to 4 orders of magnitude) PCB volatilization rate than capped sediment. Therefore, all CDF design options will include capping prior to exposure of contaminated sediment to the atmosphere. Rainfall runoff from the clean cap is not expected to present a problem with PCB release (see Report 4). Covering the CDFs with clean sediment and a geomembrane cap will cut off the bioturbation pathway.

CAD filling

17. Features of CAD options for this project are presented in Part V of the main text. The CAD facility is simply an area in the estuary that will be excavated to approximately 10- to 15-ft depth by dredging sediment to fill the CDF. Contaminated dredged material will be placed in the bottom of the CAD cell by a submerged diffuser attached to the end of the pipeline from the dredge. The diffuser is designed to release the slurry parallel to the bottom of the site and at a velocity sufficiently low to minimize upper water column impacts. However, the water that separates from the dredged material slurry as the sediment settles to the bottom will contain fine particulates with attached contaminants and contaminants dissolved in the water. These contaminants will be transported by currents created by the dredging operation and by currents in the estuary. The heavier suspended sediment particles will settle in the CAD cell, and some of the dissolved contaminants will become attached to finer suspended sediment that may eventually settle on their own or aggregate and settle more rapidly.

18. The dredged material slurry undergoes compression settling and self-weight consolidation in the CAD cell in a manner similar to that occurring in the CDF. These processes expel pore water from the sediment. This pore water may move upward into the water column or downward into the saturated zone below the CAD cell. Most of the consolidation and water loss will take place prior to placing the cap, and this represents a potential contaminant release during the disposal operation. Long-term releases from CAD disposal could result from a gradient caused by a higher water table on the shore compared with the water elevation of the estuary. This gradient may

push water through the contaminated material in the CAD and potentially through the cap (see Figure 9 of main text). The low permeability of the consolidated dredged material and the attenuation of contaminants through the cap will limit the magnitude of this source of contaminants to surface water. Quantification of this release rate requires extensive knowledge of ground-water movement and is beyond the scope of this study.

19. Transport in water is the primary pathway for loss of contaminants from the CAD filling operation. Volatilization losses will be minimized by maintaining the discharge pipe below the water.

CAD after filling

20. Placement of dredged material in the CAD facility returns the contaminated sediment to environmental conditions similar to those existing in the bottom of the harbor where the sediment originated. The advantage of the CAD site is that contaminants are separated from the water column by a layer of cleaner sediment. This clean cap prevents direct contact of the contaminated sediment with the water column, eliminates resuspension of contaminated sediment, attenuates contaminants that may move or diffuse through the cap, and reduces bioturbation with the contaminated sediment. As long as the integrity of the cap is maintained, contaminant losses from the CAD site will be minimal. Truitt (1986) reported on chemical studies of the Duwamish Waterway capping demonstration project, where vibracore sediment samples were collected at 4-cm intervals through a layer of capping material and a layer of contaminated sediment. Analyses of these samples for lead and PCB indicated that the cap effectively contained the contaminated dredged material.

Contaminant Release Estimates

Testing protocols

21. Procedures for estimating contaminant releases from dredged material disposal operations for several transport mechanisms have been developed and verified. Specific testing protocols available for various pathways and transport mechanisms are discussed in Francingues et al. (1985). Testing protocols for surface- and ground-water pathways have been applied to New Bedford sediment by this EFS. Applicable testing protocols and the transport mechanism(s) they address are listed below:

Testing Protocol	Pathway	Transport Mechanism
Modified elutriate	Surface water	Soluble and suspended contaminants from CDF during filling
Standard elutriate	Surface water	Soluble contaminants from open-water disposal
Leaching	Ground water	Soluble contaminants from confined disposal
Capping	Surface water	Soluble contaminants from CAD after filling
Surface runoff	Surface water	Soluble and suspended contaminants from CDF after filling

22. The estimates presented herein are based on results for elutriate and leachate testing of the composite sample collected for the US Army Corps of Engineers (USACE) EFS and evaluation of sediment resuspension and settling rates predicted by field studies and a vertically averaged, numerical sediment transport model.

Application of testing protocols

23. Laboratory tests. The principal data needed to estimate contaminant releases during dredging and disposal operations are the suspended sediment concentrations, particulate-associated contaminant concentrations, and soluble contaminant concentrations. Standard elutriate tests (Report 3), modified elutriate tests (Report 3), leaching tests (Report 5), and surface runoff tests (Report 4) were selected as the best available laboratory methods for providing these data. The standard elutriate has been applied to soluble releases during open-water disposal of dredged material (Brannon 1978), and the modified elutriate has been applied to soluble and particle-bound releases from diked disposal sites for dredged material (Palermo 1986). Leaching tests are applicable to releases of pore water and leachate from CDFs and CAD options. Surface runoff data are applicable to CDFs that have been filled and capped with a layer of less contaminated material (<100 ppm PCB) from the Upper Estuary.

24. Assumptions and basic data. Tables D1, D2, and D3 list the production data, sediment resuspension and release rates, and sediment escape rates used to estimate sediment flux at the Coggeshall Street Bridge during the dredging, CDF disposal, and CAD disposal operations, respectively. Production rates and fluxes are based on an 800 cu yd per day production rate, an in situ

water content of 111 percent, and a slurry sediment concentration of 125 g/ℓ. The ratio for volume of slurry produced per volume of in situ sediment dredged is 5.3.

25. Contaminant concentrations associated with suspended sediment and dissolved contaminant concentrations are based on standard and modified elutriate tests for the EFS composite sediment sample (Report 3). Total PCB Aroclor concentration of this sediment was 1,500 mg/kg. Water used for the elutriate tests was collected from the Upper Estuary.

Dredging

26. Sediment resuspension during dredging. Estimates of contaminant release from the dredging plant begin with the basic flux rate assumption of 40 g of sediment resuspended per second. This number is based on field data collected during the box-coring operation for collection of the composite sample for the USACE EFS (Report 2). Water column suspended sediment concentrations were measured during the box-coring operation at 5- and 50-yd radii of the sampling barge. Although this was a mechanical dredging activity on a relatively small scale, the barge was operating in shallow water and resuspended the material by direct contact with the bed and by prop wash, in addition to dropping and raising the corer. Average sediment concentrations 50 yd from the barge were 80 mg/ℓ above background. The concentrations observed were fit with a two-dimensional vertically averaged plume model to estimate the 40 g/sec sediment resuspension rate.

27. The sediment resuspension rate of 40 g/sec represents 0.4 percent of the sediment mass dredged and is equivalent to 2 kg sediment resuspended per cubic metre of sediment dredged. Nakai (1978) has reported sediment resuspension rates in fine-grained material from 5 kg/cu m to as high as 45 kg/cu m for a large dredge pumping a sediment with 35 percent clay. Sediment removal operations from the Upper Estuary will dredge a material with less than 20 percent clay and will employ specialized equipment, dredging operational controls, and silt curtains to minimize the rates of resuspension. Therefore, the assumed rate of resuspension (40 g/sec) is thought to be an acceptable estimate of the rate for project conditions. The New Bedford Superfund Pilot Study will provide site-specific field data to refine the estimates of sediment flux rate from dredging.

28. Sediment transport from the Upper Estuary. Only a portion of the sediment released at the dredge will be transported away from the site and

through the bridge. The values given as fraction of sediment escaping at the bridge (Table D1) are based on results from numerical hydrodynamic and sediment transport modeling described in Report 2.

29. Relationship of contaminants to sediment resuspension. The mass of contaminant associated with sediment resuspension by the dredge is based on total and soluble contaminant concentrations from elutriate tests (Report 3). The standard elutriate value was chosen for PCBs because this test has been more often related to effects on the water column (Ludwig, Sherrard, and Amende 1988). Modified elutriate data were used for the metals where quality standard elutriate data were not available. Concentrations on suspended solids were applied directly to the sediment flux from the bridge to calculate contaminant releases associated with sediment transport. Estimation procedures for mass flux rates for soluble releases from the dredge have not been developed. The approach used for this study is to relate the soluble contaminant concentration in the elutriate to the suspended solids in the elutriate and assume that the soluble releases are proportional to the sediment resuspension and transport rate. This approach represents a worst-case scenario since the elutriate test simulates mixing all of the sediment removed by dredging with site water. In reality, only the resuspended sediment and a fraction of the pore water mix with the water column during dredging.

30. Calculations. Step-by-step calculations of contaminant mass released at the bridge for PCB and heavy metals are presented in Table D1. Because of the uncertainties in dredge resuspension rates, variability in sediment characteristics, and the need for conservatism, a safety factor of 2 times the estimated contaminant release rates is applied to the release rates calculated by the above procedure. The releases that are presented represent the more contaminated sediment in the estuary and should be greater than the average release rates for dredging all of the Upper Estuary. However, actual releases are expected to sometimes exceed the daily release rates shown because of hot spots, unusual sediment physical characteristics for some areas, and extremes of production rates, tide ranges, and climatic conditions.

31. Controls to minimize dredging releases. Silt curtains or screens will also be employed around the dredging operation to reduce the transport of suspended sediment and associated contaminants away from the dredge. The contaminant release estimates do not account for this containment. However, the

containment effectiveness for the silt curtains will be similar for the dredging component of all of the options considered by this study.

Evaluation of CDF effluent

32. Effluent suspended solids. Estimates of the suspended sediment released from the CDF are presented in Table D2. Laboratory settling column data for the EFS composite sample were used in the procedure outlined by Palermo (1985) to estimate the effluent suspended solids from the primary cell of the CDF. Results from bench-scale jar tests performed for the EFS indicate that more than 50-percent additional suspended solids reduction can be achieved in the secondary cell following polymer flocculation. These estimates indicate that an effluent suspended solids concentration of 66 mg/ℓ can be attained. During the initial stages of filling of the CDF with contaminated sediment, much longer settling times will be available in the CDF.

33. CDF effluent contaminants. Contaminant release from the CDF discharge during dredging operations overflow is calculated directly from suspended sediment contaminant concentrations and dissolved contaminant concentrations observed in the modified elutriate test and from the dredge flow rate. Step-by-step mass fluxes of PCB and heavy metals are presented in Table D2. A safety factor of 2× is also applied to these fluxes for the same reasons described above.

Evaluation of CAD effects on the estuary water column

34. Suspended solids concentrations. A predictive tool for estimating the mass of suspended sediment released in the CAD cell during filling has not been developed and verified. The CAD cell could be considered as a semiconfined underwater settling area. The cells provide a volumetric retention time similar to CDFs. Minimum CAD volume is 16,000 cu yd for the 2-ft depth (CAD option A, cell B1). Application of settling test data in a manner similar to that for a CDF yields a suspended solids concentration on the order of 500 mg/ℓ or about 0.4 percent of the sediment dredging rate. All other CAD cells are 5 to 10 times larger in surface area and provide much longer detention times for settling.

35. Other studies of sediment loss during open-water disposal of dredged material, generally reported where dredging depths were greater than 50 ft, have estimated sediment losses in the water column on the order of 1 to 5 percent of the original sediment mass (Truitt 1986). Placing sediment in

the CAD cell with the submerged diffuser will more efficiently place sediment in the bottom of the cell than conventional open-water disposal. Use of the submerged diffuser for a Calumet Harbor, Illinois, project demonstrated that discharged dredged material was confined to the lower 20 percent of the water column with no increase in suspended solids above that point (McLellan and Truitt 1986). Directly comparable data for the release rate are not available. Calculations shown in Table D3 assume a sediment release of 1 percent of the dredging rate, which is greater (1,250 mg/ℓ) than the settling test prediction but lower than some estimates in the literature.

36. Contaminant fluxes. The PCB release rates for the CAD, which are presented step-by-step in Table D3, are based on suspended and soluble PCB concentrations from the standard elutriate test. Use of the standard elutriate test for estimating soluble releases during open-water disposal of dredged material is consistent with routine use of this test for evaluating open-water disposal of dredged material. Heavy metals releases are based on results from modified elutriate tests of estuary sediment (Report 3). A 2× safety factor was also applied to calculated flux rates to yield the estimates used in this report.

Estimates of leachate contaminant releases

37. To calculate the rates of contaminant loss from CDFs and CAD cells, the concentrations of contaminants and the rate of leachate seepage through the dikes and/or foundation of the site must be estimated. Evaluation of leachate quality is presented in Report 5. Results from the batch leaching tests provide a basis for a conservative estimate of leachate and pore water quality for dredged material placed in CDFs and CAD cells.

38. Leachate quality. Leachate quality will be estimated from batch leaching test data available for the first step of the sequential batch leach test using saline water as the fluid, as recommended in Report 5. Estimated leachate concentrations are given in Table D4. These concentrations are worst-case estimates because they are based on the WES estuary composite sediment and because batch leaching tests generally overestimate pore water concentrations for a flow-through system. Peak PCB concentrations for permeameter leachate tests were an order of magnitude lower than the batch leachate value shown in Table D4. Peak permeameter values for metals were

generally higher than the batch test values, which was explained as the salinity washout phenomenon in Report 5.

39. Table D4 compares the estimated leachate concentrations with the maximum contaminant levels (MCL) established under the Safe Drinking Water Act and with marine water quality criteria. The estimated leachate concentrations do not exceed MCLs for any of the metals tested. Average leachate concentrations for PCB, copper, lead, nickel, and zinc exceed the chronic criteria for marine waters. The only acute water quality criteria exceeded are for copper and PCB. However, it must be recognized that the only locations these concentrations exist are within the dredged material. Passage of leachate through the dikes or bottoms of disposal facilities will attenuate contaminants to some degree. Once the contaminants reach the waterway, they will be quickly diluted. The only contaminant of major concern for migration with leachate is PCBs.

40. Leachate volumes for CDFs. The quantity of leachate crossing the CDF boundaries depends on local hydraulic gradients and the characteristics of the foundation materials. However, information on boundary characteristics and local ground-water flow is not available. Therefore, this analysis will assume that the foundation is free draining, i.e., there is no resistance to flow at the boundary of the CDF. This condition represents a worst-case scenario because it is physically impossible to have a foundation with no resistance to flow. Also, water flowing through the dredged material will be assumed to depend on drainage of pore water in the dredged material after initial settling, net water input from the surface of the CDF, hydraulic gradient in the CDF, and infiltration characteristics of the dredged material.

41. All design options that include CDFs call for placement of an impermeable cap on the surface of the contaminated dredged material to minimize the net freshwater input from the surface. Report 3 showed that washout of salinity from the dredged material had a marked increase on release of contaminants from sediment solids. Therefore, the cap provides both the benefit of reducing the flow of water through the dredged material and the benefit of reducing the desorption of contaminants from sediment to pore water or leachate.

42. Ground water beneath in-water CDFs is expected to flow toward the estuary. However, additional geohydrological data and modeling would be required to confirm site-specific flow patterns and rates for the CDF sites

and the estuary area. Leachate exiting the boundaries of the upland CDFs may enter the ground water or the estuary.

43. Estimates of vertical percolation through the CDF bottom were made using a water balance from consolidation of the dredged material and the US Environmental Protection Agency's Hydraulic Evaluation of Landfill Performance (HELP) computer model (Schroeder et al. 1984). HELP models hydrologic movement of water across, into, through, and out of landfills. It accepts climatologic, soil, and design data and uses a solution technique that accounts for the effects of surface storage, runoff, winter cover, infiltration, percolation, evapotranspiration, and soil moisture storage. The version (HELP2) of the model used for this analysis is adaptable to dredged material because it can account for the saturated conditions initially present in a CDF.

44. During a 10-year simulation period, HELP2 computed the percolation rate from the base of a typical CDF profile, including a geomembrane cap, to average 1.6 in. of water per year. At the end of the tenth year, the percolation rate was 0.36 in. per year. Leachate contaminant fluxes are based on 10 years at 1.6 in. per year and 20 years at 0.36 in. per year, yielding a total of 24 in. for the 30 years following placement and capping in the CDFs.

45. Prior to the percolation losses from CDFs after capping as predicted by HELP2, additional pore water is expelled from the dredged material slurry as the sediment consolidates. The change in elevation of sediment with time in a typical CDF design for New Bedford is illustrated in Figure D1. This figure was developed from output of the Primary Consolidation and Desiccation of Dredged Fill (PCDDF) model (Cargill 1985). One curve represents consolidation with a relatively free-draining foundation (hydraulic conductivity = 1 ft/day), and the other represents a less permeable foundation (0.0001 ft/day). The rate of consolidation differs for the first 1 to 2 years, but by the end of the third year, consolidation levels off for both conditions. The change in elevation and volume of sediment is accompanied by the release of an equivalent volume of water. This water is released in all directions, i.e., through the bottom, sides, and surface of the CDF. Water that is released to the surface is controllable by wastewater treatment processes. However, the evaluation of leachate releases for unlined CDFs will assume that all of this volume escapes the boundaries of the CDF.

46. Water balance for dredging and disposal. Quantification of fluxes from CDF and CAD alternatives must balance water present with in situ sediment and water added during hydraulic dredging against water losses as effluent, leachate, and water remaining with the disposed sediment. Figure D2 illustrates a water balance for dredging New Bedford sediment on the basis of 1 cu yd of in situ sediment. A volume of 4.3 cu yd of estuary water is added for each volume of sediment removed based on assumed sediment concentrations in situ and in the dredged material slurry. For the CDF alternative, additional precipitation will be added during disposal operations. Most of the precipitation will be removed as surface runoff or will evaporate. Figure D2 assumes that 24 in. of rainfall will infiltrate the surface during the 1- to 2-year operational period prior to covering of the contaminated sediment and consolidation of the dredged material. The water balance shows that an estimated 3.05 cu yd of effluent is produced, and 1.54 cu yd of leachate is produced for each cubic yard of sediment removed and placed in a CDF. The effluent is released to surface water, and leachate may be released to surface or ground water, or both.

47. CAD pore water losses. The CAD alternative does not have the rainfall contribution factor and produces an estimated 3.05 cu yd of water released to the water column during dredging and 1.18 cu yd of leachate, or pore water, lost. The CAD leachate will likely be released to the surface-water pathway.

Comparison of contaminant mass releases

48. Tables D5 and D6 present estimates of the total mass of PCBs released by the CDF and CAD options, respectively, considered in this study. Estimates for copper releases are presented in Tables D7 and D8. The numbers presented include totals for the project implementation phase of the project and for the postproject phase, which extends to 30 years after filling a CDF or CAD site. The bases for the numbers are the data presented in Tables D1-D3, the volume of sediment removed for each disposal option as described in the main text, the leachate and effluent volumes discussed above, and the leachate concentrations from the sequential batch leachate test.

49. CDF design options. Tables D5 and D7 show that the component contributing the majority of the contaminant loads for the CDF alternative is the dredging operation. For the design options that include effluent treatment, PCB removal is based on 90-percent removal of PCB associated with suspended

solids by filtration (options A2 and B2) and 99-percent removal of dissolved PCB by carbon adsorption or UV/hydrogen peroxide for options A3, B3, C, and D. The options that have lined CDFs (C and D) include carbon adsorption for leachate collected by the liner system. Copper removal by the effluent treatment processes is based on removal of only the copper associated with the suspended sediment.

50. Because dredging release estimates predominate in this analysis of contaminant migration, the more extensively controlled design options (C and D) lose some of their advantage due to the additional volume of sediment that must be dredged for these design options. For example, option A3, which consists of unlined CDFs and effluent treatment, produces less total PCB release than option D, which consists of lined CDFs and effluent/leachate treatment. This situation may not occur if the dredging releases are overestimated by a wide margin. If the dredging releases were reduced by a factor of 2, then the ranking follows the logical progression of more controls produce lower contaminant releases. This order is illustrated by the relation of the releases from the CDF component in Tables D5 and D7.

51. CAD design options. Tables D6 and D8 illustrate the life-of-the-project contaminant releases associated with the CAD design options. The CAD releases to the water column during placement of contaminated sediment in the CAD cell are the larger contaminant release component for options B and C. Releases from the dredge are greater than CAD filling for options A1, A2, and A3 because the more contaminated sediment is placed in a CDF for this option, reducing the losses during CAD filling.

Table D1

Estimate of Contaminant Flux for Dredging

Parameter Description for Dredging Component	Units	PCB Composite Sediment	PCB Hot Spot Sediment	Cd Estuary Sediment	Cu Estuary Sediment	Pb Estuary Sediment
Dredge production rate, in situ sediment volume	cu m/hr	76	76	76	76	76
Dredge slurry flow rate	cu m/hr	405	405	405	405	405
Effective dredge operating time	hr/day	8	8	8	8	8
Daily dredge production rate	cu m/day	611	611	611	611	611
Daily dredge slurry flow	cu m/day	3,238	3,238	3,238	3,238	3,238
In situ sediment conc. (water content=111%)	g/liter	660	660	660	660	660
Dredge slurry total suspended solids (TSS) conc.	g/liter	125	125	125	125	125
Solids pumping rate, dry weight	kg/day	403,000	403,000	403,000	403,000	403,000
Sediment resuspension rate at dredge, TSS	g/sec	40	40	40	40	40
Daily sediment resuspension rate at dredge, TSS	kg/day	1,152	1,152	1,152	1,152	1,152
In situ sediment contaminant conc.	mg/kg	1,500	8,400	36	1,330	1,000
Elutriate contaminant conc., whole water	mg/liter	0.18	3.04	0.0059	0.18	0.026
Elutriate dissolved contaminant conc.	mg/liter	0.11	0.58	0.0025	0.02	0.011
Elutriate total suspended solids (TSS) conc.	mg/liter	120	437	148	148	320
Elutriate contaminant conc. on sediment	mg/kg	583	5,627	23	1,101	47
Elutriate dissolved contaminant conc./TSS	mg/kg	917	1,330	17	115	34
Contaminant flux at dredge with TSS	kg/day	0.67	6.48	0.03	1.27	0.054
Contaminant flux at dredge, dissolved	kg/day	1.06	1.53	0.02	0.13	0.040
Total contaminant flux at dredge	kg/day	1.73	8.01	0.05	1.40	0.094
TSS escaping bridge (% fines=46, % escape=68)	fraction	0.31	0.31	0.31	0.31	0.31
TSS escaping bridge	kg/day	360	360	360	360	360
Contaminant flux at bridge with TSS	kg/day	0.21	2.0	0.0083	0.40	0.017
Contaminant flux at bridge, dissolved	kg/day	0.33	0.48	0.0061	0.041	0.012
Total contaminant flux at bridge	kg/day	0.54	2.5	0.014	0.44	0.029
Contaminant flux at bridge with TSS (2X safety)	kg/day	0.4	4	0.02	0.8	0.03
Contaminant flux at bridge, dissolved (2X safety)	kg/day	0.7	1	0.01	0.08	0.02
Total contaminant flux at bridge (2X safety)	kg/day	1	5	0.03	0.9	0.06

Table D2

Estimate of Contaminant Flux for CDF Effluent

Parameter Description for CDF Component	Units	Composite Sediment	Hot Spot Sediment	Cd Estuary Sediment	Cu Estuary Sediment	Pb Estuary Sediment
Dredge production rate, in situ sediment volume	cu m/hr	76	76	76	76	76
Dredge slurry flow rate	cu m/hr	405	405	405	405	405
Effective dredge operating time	hr/day	8	8	8	8	8
Daily dredge production rate	cu m/day	611	611	611	611	611
Daily dredge slurry flow	cu m/day	3,238	3,238	3,238	3,238	3,238
In situ sediment conc. (water content=111%)	g/liter	660	660	660	660	660
Dredge slurry total suspended solids (TSS) conc.	g/liter	125	125	125	125	125
Solids pumping rate, dry weight	kg/day	403,000	403,000	403,000	403,000	403,000
Effluent TSS conc. (82 hr settling & flocculation)	mg/liter	66	54	66	66	66
Daily TSS release from CDF	kg/day	214	175	214	214	214
In situ sediment contaminant conc.	mg/kg	1,500	8,400	35	1,730	2,013
Elutriate contaminant conc., whole water	mg/liter	0.21	1.20	0.0059	0.180	0.026
Elutriate dissolved contaminant conc.	mg/liter	0.10	0.46	0.0025	0.017	0.011
Elutriate total suspended solids (TSS) conc.	mg/liter	320	132	148	148	320
Elutriate contaminant conc. on sediment	mg/kg	325	5,644	23	1,101	47
Elutriate dissolved contaminant conc./TSS	mg/kg	325	3,447	17	115	34
Contaminant flux from CDF with TSS	kg/day	0.07	0.99	0.0049	0.24	0.01
Contaminant flux from CDF, dissolved	kg/day	0.34	0.60	0.0081	0.06	0.04
Total contaminant flux from CDF	kg/day	0.41	1.59	0.013	0.29	0.05
TSS escaping bridge from lower estuary	fraction	0.76	0.76	0.76	0.76	0.76
TSS escaping bridge	kg/day	162	133	162	162	162
Contaminant flux at bridge with TSS	kg/day	0.053	0.75	0.0037	0.18	0.0076
Contaminant flux at bridge, dissolved	kg/day	0.34	0.60	0.0081	0.055	0.036
Total contaminant flux at bridge	kg/day	0.39	1.4	0.012	0.23	0.043
Contaminant flux at bridge with TSS (2X safety)	kg/day	0.1	2	0.007	0.4	0.02
Contaminant flux at bridge, dissolved (2X safety)	kg/day	0.7	1	0.02	0.1	0.07
Total contaminant flux at bridge (2X safety)	kg/day	1	3	0.02	0.5	0.1

Table D3

Estimate of Contaminant Flux for CAD Filling Operations

Parameter Description for CAD Component	Units	Composite Sediment	Hot Spot Sediment	Cd Estuary Sediment	Cu Estuary Sediment	Pb Estuary Sediment
Dredge production rate, in situ sediment volume	cu m/hr	76	76	76	76	76
Dredge slurry flow rate	cu m/hr	405	405	405	405	405
Effective dredge operating time	hr/day	8	8	8	8	8
Daily dredge production rate	cu m/day	611	611	611	611	611
Daily dredge slurry flow	cu m/day	3,238	3,238	3,238	3,238	3,238
In situ sediment conc. (water content=111%)	g/liter	660	660	660	660	660
Dredge slurry total suspended solids (TSS) conc.	g/liter	125	125	125	125	125
Solids pumping rate, dry weight	kg/day	403,000	403,000	403,000	403,000	403,000
CAD effluent TSS concentration at discharge point	mg/l	1,250	1,250	1,250	1,250	1,250
Daily sediment release from CAD at discharge point	kg/day	4,048	4,048	4,048	4,048	4,048
In situ sediment contaminant conc.	mg/kg	1,500	8,400	36	1,330	1,000
Elutriate contaminant conc., whole water	mg/liter	0.18	3.04	0.0059	0.18	0.026
Elutriate dissolved contaminant conc.	mg/liter	0.11	0.58	0.0025	0.0170	0.011
Elutriate total suspended solids (TSS) conc.	mg/liter	120	437	148	148	320
Elutriate contaminant conc. on sediment	mg/kg	583	5,627	23	1,101	47
Elutriate dissolved contaminant conc./TSS	mg/kg	917	1,330	17	115	34
Contaminant flux at dredge with TSS	kg/day	2.36	22.78	0.09	4.46	0.19
Contaminant flux at dredge, dissolved	kg/day	0.36	5.38	0.01	0.06	0.04
Total contaminant flux at dredge	kg/day	2.72	28.16	0.10	4.51	0.23
TSS escaping bridge from upper estuary	fraction	0.52	0.52	0.52	0.52	0.52
TSS escaping bridge	kg/day	2,105	2,105	2,105	2,105	2,105
Contaminant flux at bridge with TSS	kg/day	1.2	12	0.048	2.3	0.099
Contaminant flux at bridge, dissolved	kg/day	0.36	5.4	0.0081	0.055	0.036
Total contaminant flux at bridge	kg/day	1.6	17	0.056	2.4	0.13
Contaminant flux at bridge with TSS (2X safety)	kg/day	2.5	20	0.10	5	0.2
Contaminant flux at bridge, dissolved (2X safety)	kg/day	0.7	10	0.02	0.1	0.1
Total contaminant flux at bridge (2X safety)	kg/day	3	30	0.1	5	0.3

Table D4

Estimated Contaminant Flux by Leachate Seepage from CDFs

Contaminant	Maximum Contaminant Level* µg/ℓ (ppb)	Marine Water Quality Criteria Acute µg/ℓ (ppb)	Marine Water Quality Criteria Chronic µg/ℓ (ppb)	Batch Leachate Concentration µg/ℓ (ppb)	Peak Anaerobic Leachate Concentration** µg/ℓ (ppb)
Arsenic	50	69	36	16	
Cadmium	10	43	9.3	0.17	2.9
Chromium	50	10,300	17	375	
Copper		2.9	2.9	8.0	17
Lead	50	140	5.6	9.0	10
Nickel	--	75	8.3	57	58
Zinc	--	95	86	90	14
PCB (1242 + 1254)	--	10	0.03	266	21

* Represents level specified for compliance with Safe Drinking Water Act.

** From permeameter leach test.

Table D5

Total Mass PCB Released for CDF Design Options

			Alt No. CDF A1	Alt No. CDF A2	Alt No. CDF A3	Alt No. CDF B1	Alt No. CDF B2	Alt No. CDF B3	Alt No. CDF C	Alt No. CDF D
Sediment Volume cu yd		Dredge	484,000	484,000	484,000	514,000	514,000	514,000	574,000	633,000
		CDF	484,000	484,000	484,000	514,000	514,000	514,000	574,000	633,000
		CAD								
		PCB kg/cu yd	PCB kg	PCB kg	PCB kg	PCB kg	PCB kg	PCB kg	PCB kg	PCB kg
Dredge	Dissolved	0.00083	400	400	400	424	424	424	474	523
	Suspended	0.00053	254	254	254	270	270	270	302	333
	Total	0.00135	654	654	654	695	695	695	776	855
CDF	Dissolved	0.00050	244	244	2	259	259	3	3	3
	Suspended	0.00007	35	3	0	37	4	0	0	0
	Subtotal	0.00058	279	247	3	296	263	3	3	4
	Leach-short	0.00031	150	150	150	159	159	159	84	2
	Leach-long		40	40	40	40	40	40	21	0
	Total	0	469	437	193	495	462	202	107	6
CAD	Dissolved	0.00050								
	Suspended	0.00180								
	Subtotal	0.00230								
	Leach-short	0.00024								
	Leach-long									
	Total	0.00254	0	0	0	0	0	0	0	0
	GRAND TOTAL		1,123	1,091	847	1,190	1,156	897	883	861

Table D6

Total Mass PCB Released for CAD Design Options

			Alt No. CAD A1	Alt No. CAD A2	Alt No. CAD A3	Alt No. CAD B	Alt No. CAD C
Sediment Volume cu yd		Dredge	497,905	497,905	497,905	552,972	568,872
		CDF	228,276	228,276	228,276	159,083	222,993
		CAD	269,629	269,629	269,629	393,889	698,255
		PCB kg/cu yd	PCB kg	PCB kg	PCB kg	PCB kg	PCB kg
Dredge	Dissolved	0.00083	411	411	411	457	470
	Suspended	0.00053	262	262	262	291	299
	Total	0.00135	673	673	673	747	769
CDF	Dissolved	0.00050	115	115	1	80	112
	Suspended	0.00007	16	2	0	11	16
	Subtotal	0.00058	131	117	1	92	128
	Leach-short	0.00031	71	71	71	49	69
	Leach-long		23	23	23	16	14
	Total	0	225	210	95	157	211
CAD	Dissolved	0.00050	136	136	136	198	352
	Suspended	0.00180	485	485	485	708	1,256
	Subtotal	0.00230	621	621	621	907	1,607
	Leach-short	0.00024	65	65	65	95	168
	Leach-long						
	Total	0.00254	685	685	685	1,001	1,775
	GRAND TOTAL		1,583	1,569	1,453	1,906	2,755

Table D7

Total Mass Copper Released for CDF Design Options

			Alt No. CDF A1	Alt No. CDF A2	Alt No. CDF A3	Alt No. CDF B1	Alt No. CDF B2	Alt No. CDF B3	Alt No. CDF C	Alt No. CDF D
Sediment Volume cu yd		Dredge	484,000	484,000	484,000	514,000	514,000	514,000	574,000	633,000
		CDF	484,000	484,000	484,000	514,000	514,000	514,000	574,000	633,000
		CAD								
		Cu kg/cu yd	Cu kg	Cu kg	Cu kg	Cu kg	Cu kg	Cu kg	Cu kg	Cu kg
Dredge	Dissolved	0.00010	50	50	50	53	53	53	59	66
	Suspended	0.00099	480	480	480	510	510	510	570	628
	Total	0.00110	530	530	530	563	563	563	629	694
CDF	Dissolved	0.00008	38	38	38	41	41	41	45	50
	Suspended	0.00026	125	12	1	132	13	1	1	2
	Subtotal	0.00034	163	51	40	173	54	42	47	52
	Leach-short	0.00001	5	5	5	5	5	5	5	6
	Leach-long		1	1	1	1	1	1	1	1
	Total	0	169	56	45	179	60	48	53	59
CAD	Dissolved	0.00008								
	Suspended	0.00333								
	Subtotal	0.00341								
	Leach-short	0.00001								
	Leach-long									
	Total	0.00342	0	0	0	0	0	0	0	0
	GRAND TOTAL		699	587	576	742	623	611	682	753

Table D8

Total Mass Copper Released for CAD Design Options

			Alt No. CAD A1	Alt No. CAD A2	Alt No. CAD A3	Alt No. CAD B	Alt No. CAD C
Sediment Volume cu yd		Dredge	497,905	497,905	497,905	552,972	568,872
		CDF	228,276	228,276	228,276	159,083	222,993
		CAD	269,629	269,629	269,629	393,889	698,255
		Cu kg/cu yd	Cu kg	Cu kg	Cu kg	Cu kg	Cu kg
Dredge	Dissolved	0.00010	52	52	52	57	59
	Suspended	0.00099	494	494	494	549	564
	Total	0.00110	546	546	546	606	623
CDF	Dissolved	0.00008	18	18	18	13	18
	Suspended	0.00026	59	6	1	41	57
	Subtotal	0.00034	77	24	19	54	75
	Leach-short	0.00001	2	2	2	1	2
	Leach-long		1	1	1	0	0
	Total	0	80	27	21	56	78
CAD	Dissolved	0.00008	21	21	21	31	55
	Suspended	0.00333	899	899	899	1,314	2,329
	Subtotal	0.00341	921	921	921	1,345	2,384
	Leach-short	0.00001	2	2	2	3	5
	Leach-long						
	Total	0.00342	922	922	922	1,348	2,389
	GRAND TOTAL		1,548	1,495	1,490	2,009	3,090

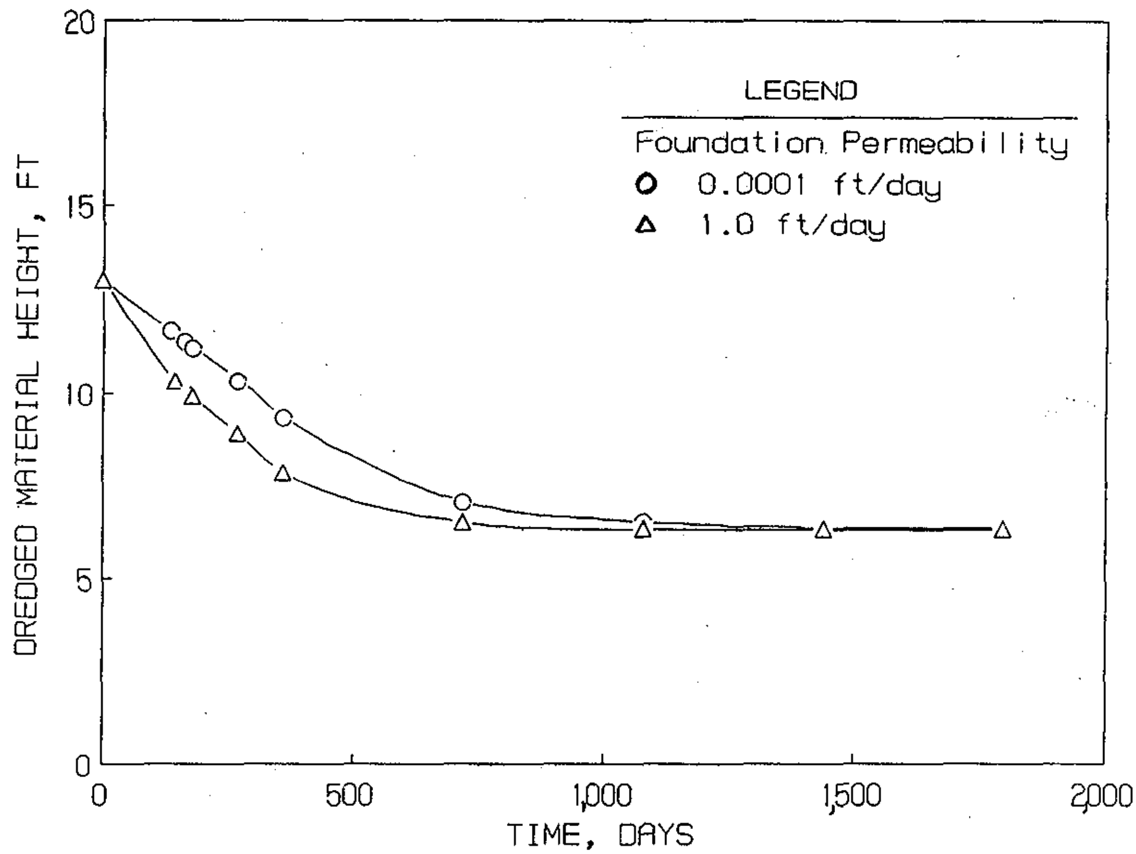

Figure D1. Consolidation rate for Upper Estuary dredged material

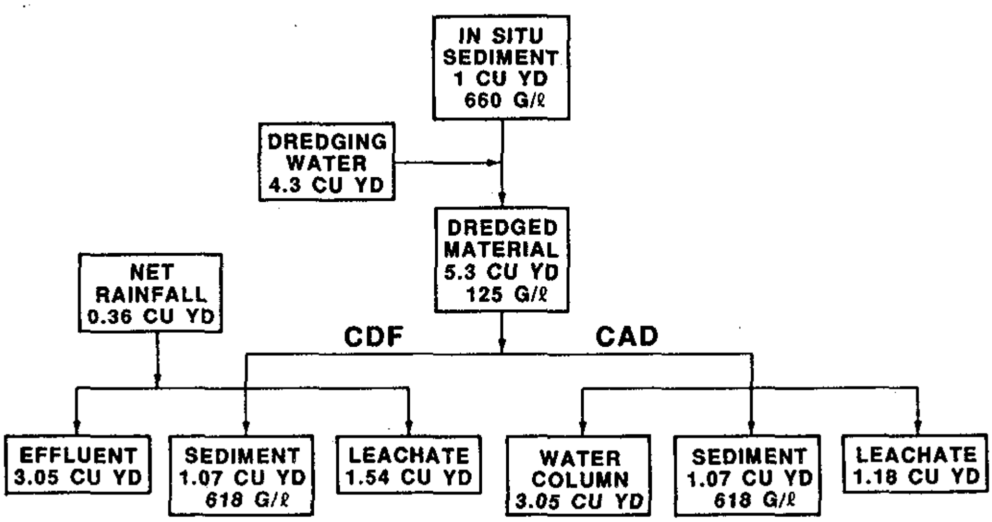

Figure D2. Water balance for dredging, CDF, and CAD disposal